Volume 27 DECEMBER 26, 1952 Number 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

INYOKERN-PASADENA MEETING

AT

U. S. NAVAL ORDNANCE TEST STATION, INYOKERN,
AND THE
CALIFORNIA INSTITUTE OF TECHNOLOGY

DECEMBER 26, 27, 29, AND 30, 1952

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SIX ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published six times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published six times a year, once in January, once in March, once in May, once in June, once in November, and once in December, at Prince and Lemon Streets, Lancaster, Pennsylvania.

Entered as second class matter, December 27, 1949, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized Nov. 30, 1948.

DECEMBER 26, 1952 Vol. 27, No. 6

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INYOKERN–PASADENA MEETING, DECEMBER 26, 27, 29, AND 30, 1952

THE 316th meeting of the American Physical Society will be held at the U. S. Naval Ordnance Test Station, Inyokern, on Friday and Saturday, December 26 and 27, 1952, and at the California Institute of Technology, Pasadena, December 29 and 30, 1952. Invited papers on the Pasadena programme of the Society will be given by R. L. Kyhl, C. Kittel, Robert Hofstadter and Asher Kantz, J. E. Goldman, R. V. Langmuir, R. B. Leighton, R. C. Feynmann, A. Guinier, and Fred Hoyle. All of the invited papers will be given in Room 201 of the Norman Bridge Laboratory.

On Friday, December 26, at Inyokern there will be a symposium and a discussion session on the spectroscopy of combustion, and on Saturday, December 27, invited papers in fluid dynamics and a discussion on the topic of "Wakes and Jets." Arrangements will be made for a tour of the Michelson Laboratory on Friday, and for a tour of the range on Saturday. Invited papers at Inyokern will be given by H. W. Liepmann, E. P. Cooper, M. S. Plesset, John Laufer, M. Z. Krzywoblocki, C. W. Horton, S. Silverman, R. G. W. Norrish, G. Porter, A. G. Gaydon, H. G. Wolfhard, and P. Swings. All of the sessions will be held in the Station Theatre.

The **registration desk** will be in the library of the Norman Bridge Laboratory of Physics in Pasadena. All members and guests are urged to register, and frequently to consult the adjacent bulletin board for notices of messages and program changes. Payment of a registration fee of one dollar will be requested. There will be no registration in Inyokern.

Anyone who wishes to discuss classified material while in the Station at Inyokern should transmit his security clearance via regular military channels to the Security Officer at NOTS.

The most direct route to the Naval Ordnance Test Station from the Pasadena area is via Angeles Crest Highway to Highway No. 6. While on the Angeles Crest Highway, follow the left fork of the road marked "Palmdale." Turn right at Highway No. 6 to Palmdale and continue via Highway No. 6 to the Inyokern turn-off. If you wish to avoid the mountains, follow Route No. 6 from Los Angeles to the Inyokern turn-off. From Pasadena, 3½ to 4 hours is required for the trip.

The turn-off to Inyokern occurs about 50 miles North of Mojave on Route No. 6 and is well marked on the highway. The Naval Ordnance Test Station is located 8 miles East of the town of Inyokern.

The most direct route to the Station from the North is via Route 466 from Bakersfield to Mojave, then Route No. 6 from Mojave to the Inyokern turn-off.

Inquiries, addressed to Dr. William B. Plum, Room 20103, Michelson Laboratory, U. S. Naval Ordnance Test Station, China Lake, California, will be gladly answered. **Information regarding hotels, motor courts, and eating places** in Pasadena and vicinity will be available at the registration desk. Inquiries addressed to the Department of Physics at the California Institute of Technology will receive prompt attention.

Attention is called to the request for information concerning **travel to and from Inyokern,** which appears at the end of this Bulletin. Please send this to Inyokern promptly. Accommodations at Inyokern are limited and will be provided on a first-come-first-served basis.

Post-deadline ten-minute papers, pertaining to any recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received by the Local Secretary not later than December 19, The abstracts will not be printed. The titles of such papers as may be accepted will be announced on a blackboard near the registration desk. The papers will be given under the usual ten-minute rule at the assigned session.

Prospective meetings of the Society are scheduled to be held at Cambridge on January 22–24,

1953; at Durham, North Carolina, on March 26–28; at Washington, D. C., on April 30 and May 1–2; at Rochester, New York, on June 18–20; and at Albuquerque, New Mexico, on September 2–5.

Titles and abstracts of the papers, contributed to the Denver meeting are printed hereinafter, and in exactly this form they will reappear in an early issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, January 16, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Write out your corrections in the form "instead of ...., read ....;" do not sent in your abstract marked with corrections. Do not add anything.

Speakers must retrieve their lantern slides before leaving the room in which they spoke. The Local Committee must not be burdened with the task of saving and returning them.

The Secretary is grateful to Drs. H. V. Neher, F. T. Rogers, Jr., and A. H. Warner for their invaluable aid in the preparation of this program. He wishes also to acknowledge the sponsorship by the Office of Naval Research of the participants from England in the Inyokern Meeting.

J. KAPLAN
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

PROGRAMME

FRIDAY MORNING AT 10:00

Station Theatre

(F. E. ROACH presiding)

Invited Papers

A1. Infrared Emission Studies of Some Equilibrium and Nonequilibrium Flame Reactions. S. SILVERMAN, *Applied Physics Laboratory, The Johns Hopkins University.* (30 min.)

A2. Absorption Spectroscopy in Stationary Flames. H. G. WOLFHARD, *London, England.* (45 min.)

A3. Comets, Carbon Stars, and Combustion Phenomena. P. SWINGS, *University of Liege.* (45 min.)

A4. Quantitative Spectroscopic Investigations of Rapid Gaseous Reactions. G. PORTER, *University of Cambridge.* (45 min.)

A5. The Study of Ignition Reactions by Flash Photolysis. R. G. W. NORRISH, *University of Cambridge.* (45 min.)

A6. Spectroscopic Studies of Flames Supported by Free Atoms. A. G. GAYDON, *Imperial College, University of London.* (45 min.)

FRIDAY AFTERNOON AT 1:00

Station Theatre

(P. SWINGS presiding)

Session B

Discussion of the Invited Papers on the Spectroscopy of Combustion

---

SATURDAY MORNING AT 9:00

Station Theatre

(F. W. BROWN presiding)

Invited Papers

C1. Water Entry Theory. E. P. COOPER, *Naval Radiological Defense Laboratory, San Francisco.* (30 min.)

C2. Cavitation and Boiling. M. S. PLESSET, *California Institute of Technology.* (30 min.)

C3. Hydroacoustic Filter Networks. C. W. HORTON, *University of Texas.* (30 min.)

C4. The Effect of Turbulence on Linear Systems. H. W. LIEPMANN, *California Institute of Technology.* (30 min.)

C5. On the Stability of Benard-Karman Vortex Sheet in Compressible Flow. M. Z. KRZYWOBLOCKI, *University of Illinois and NOTS, Inyokern.* (30 min.)

SATURDAY AFTERNOON AT 1:00

Station Theatre

(M. Z. KRZYWOBLOCKI presiding)

Session D

Discussion on Wakes and Jets

Discussion Leader: M. Z. KRZYWOBLOCKI

In addition to the invited speakers on the earlier session of the day, A. B. C. Anderson and G. V. Schliestett will join the panel.

MONDAY MORNING AT 10:00

Room 201, Bridge

(H. V. NEHER presiding)

Invited Papers

E1. Microwave Physics and the Study of Solids. C. KITTEL, *University of California, Berkeley.* (45 min.)

E2. Electronic Specific Heat in Relation to the Band Structure of Transition Metals and Alloys. J. E. GOLDMAN, *Carnegie Institute of Technology.* (30 min.)

E3. Electronic X-Ray Probe for the Micro-Analysis of the Structure and Composition of Metallic Solids. ANDRE GUINIER, *University of Illinois.* (30 min.)

MONDAY AFTERNOON AT 1:30

Room 201, Bridge

(W. A. FOWLER presiding)

Contributed Papers

F1. Elastic Scattering of Protons by Li^7.* WILLIAM D. WARTERS,† *Kellogg Radiation Laboratory, California Institute of Technology.*—The elastic scattering cross section for protons in Li^7 has been measured over the proton energy range 360–1400 kev, using the variable angle 10¼-inch double-focusing magnetic spectrometer. Measurements were made at scattering angles of 50, 70, 89, 110, 130, 144, and 160 degrees in the center-of-mass system. The relative stopping cross section for protons in lithium was also measured from 200–1300 kev and was found to agree with the formula of Livingston and Bethe[1] when fitted to the results of Haworth and King[2] at low energies. The maximum ratio of observed scattering cross section to Rutherford cross section for various angles near the 441.4 kev resonance in $Li^7(p\gamma)$ is:

$\theta_{c.m.}$	50°	70°	89°	110°	130°	144°	160°
$(\sigma/\sigma_R)_{max}$	1.28	1.49	1.70	1.88	2.00	2.16	2.28

Preliminary analysis, consistent with spherically symmetric γ-radiation, indicates a $J=1$ even resonance in Be^8 formed by p wave protons.

* Assisted by the joint program of the ONR and AEC.
† National Science Foundation Predoctoral Fellow.
[1] M. S. Livingston and H. A. Bethe, Revs. Modern Phys. **9**, 245 (1937).
[2] L. J. Haworth and L. D. P. King, Phys. Rev. **54**, 48 (1938).

F2. Elastic Scattering of Protons by C^{12} and C^{13}.* EDMUND A. MILNE, *Kellogg Radiation Laboratory, California Institute of Technology.*—A variable angle, double-focusing, magnetic, proton spectrometer has been used to study the elastic scattering of protons from C^{12} near the 456-kev resonance in $C^{13}(p\gamma)$ to gain information about the excited state in the compound nucleus N^{13}. Data have been taken on $C^{12}(pp)C^{12}$ from 300 kev to 550 kev at every 10° in the center-of-mass system from 30° to 160°. Analysis of the data shows the 456-kev resonance is caused by s wave protons forming a $^2S_{\frac{1}{2}}$ state[1] in N^{13} in agreement with Goldhaber and Williamson. These measurements are being extended to the 1.7 Mev resonance in $C^{12}(p\gamma)$, and in addition the elastic scattering from $C^{13}(pp)C^{13}$ is under investigation from 0.3 to 2.0 Mev.

* Assisted by the joint program of the ONR and AEC.
[1] G. Goldhaber and R. M. Williamson, Phys. Rev. **82**, 495 (1951).

F3. The Energy Loss of Low Energy Protons and Deuterons in Gases.* H. K. REYNOLDS, D. N. F. DUNBAR, W. A. WENZEL, AND W. WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—The loss of energy of protons and deuterons passing through a gas cell has been measured over the equivalent proton energy range 25–550 kev. A monoenergetic incident beam is obtained from a Van de Graaff generator, and the energy of the transmitted particles with and without gas in the cell is measured with a magnetic spectrometer. The entrance and exit windows of the gas cell are made of thin Al of total energy loss 5–10 kev. Methods of correcting for the known variation with proton energy of the energy loss in the windows will be discussed. Changes in the window thickness under pressure, such as mechanical stretching or absorption of gas, are detected by varying the length of the gas cell. The gas pressure is measured with an oil manometer. In the pressure range of these measurements, a few mm of Hg, the energy loss in the gas has been found to be proportional to the pressure. The energy loss for protons and deuterons of the same velocity has been found to be the same within the experimental uncertainty.

* Assisted by the joint program of the ONR and AEC.

F4. The Stopping Cross Section of Several Gases for Protons and Deuterons.* D. N. F. DUNBAR, H. K. REYNOLDS, W. A. WENZEL, AND W. WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—The stopping cross section of H_2, He, air, O_2, CO_2, and NH_3 for protons and deuterons of equivalent proton energy 25–550 kev has been measured by the method described in the previous abstract. The stopping cross sections ϵ of H_2 and He exhibit a markedly different energy dependence: $\epsilon(H_2)/\epsilon(He)$ decreases from approximately 2 at $E_p=25$ kev to 1 at $E_p=550$ kev. The stopping power of O_2 relative to air varies from 0.9 at $E_p=30$ kev to 1.1 at $E_p=550$ kev. The stopping cross sections of the gaseous compounds are discussed with particular attention to the Bragg law for the addition of stopping cross sections. Range energy curves obtained from these stopping cross sections are compared with the previous measurements of the range in cloud chambers.

* Assisted by the joint program of the ONR and AEC.

F5. Q Values of the $Ne^{21}(d,\alpha)F^{19}$ and $Ne^{21}(d,p)Ne^{22}$ Reactions.* CURT MILEIKOWSKY AND WARD WHALING, *Nobel Institute of Physics, Stockholm and Kellogg Radiation Laboratory, California Institute of Technology.*—Separated

isotopic targets of Ne^{21}, which were produced at the Nobel Institute of Physics, have been used to measure the Q values of the reactions (1) $Ne^{21}(d, \alpha)F^{19}$, and (2) $Ne^{21}(d, p)Ne^{22}$. The double-focusing magnetic spectrograph was used to compare the energy of the protons and alpha-particles from these reactions with the alpha-particles from ThC and ThC′. The angle of observation and the deuteron bombarding energy were chosen so that the particles being studied and the alpha-line used for energy calibration lay nearly side by side on the photographic plate used as a detector. The Q values measured are 6.432 ± 0.010 for reaction (1) and 8.137 ± 0.011 for reaction (2). From these Q values and the mass of F^{19} the atomic masses of Ne^{21} and Ne^{22} are obtained. Other alpha-groups from reaction (1) correspond to transitions to states in F^{19} at 0.113 ±0.008 Mev and 0.192 ± 0.012 Mev above the ground state. Additional particle groups from N and Na contamination on the targets have been observed: the Q values measured are 8.613 ± 0.011 Mev for $N^{14}(d, p)N^{15}$ and 4.723 ± 0.008 Mev for $Na^{23}(d, p)Na^{24}$.

* Assisted by the joint program of the ONR and AEC and by the Swedish Atomic Committee.

F6. Angular Distribution of Gamma-Rays and Alpha-Particles from the Reaction $N^{15}(p, \alpha\ \gamma)C^{12}$.* ALFRED A. KRAUS, JR., A. P. FRENCH,† WILLIAM A. FOWLER, AND C. C. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—The reaction $N^{15}(p, \alpha\gamma)C^{12}$ exhibits strong resonance[1] at 429-, 898-, and 1210-kev proton bombarding energy. We have measured the gamma-ray angular distributions at these three resonances and the alpha-particle distributions at the 898-kev and the 1210-kev resonances. The distributions at 429 kev and 898 kev are in agreement with the following spin and parity assignments: N^{15}, $\frac{1}{2}^-$; $l_p=2$; I^{16*} (12.51 Mev), 2^- or >5; O^{16*} (12.95 Mev), 2^- or >5; $l_\alpha=1$; C^{12*} (4.432 Mev), 2^+ or >4; C^{12}, O^+. The assignments for the two O^{16*} levels are identical, but the corresponding resonances do differ in the relative amounts of channel spin zero and channel spin one occurring in the proton capture. For the 429-kev resonance the fraction of channel spin zero is 0.82, while at 898 kev it is 0.58. The 1210-kev resonance shows angular distributions in agreement with $l_p=3$; O^{16*} (13.24 Mev), 4^+ or >5; $l_\alpha=2$; C^{12*} (4.432 Mev), 2^+ or >4. The assignment for the excited state of C^{12} at 4.432 Mev is obtained independently from observations at the three resonances. The ambiguities in the assignments arise only from the fact that the theoretical behavior of levels of large angular momentum has not been completely investigated.

* Assisted by the joint program of the ONR and AEC.
† Cavendish Laboratory, Cambridge, England.
[1] Schardt, Fowler, and Lauritsen, Phys. Rev. **86**, 527 (1952).

F7. Angular Anisotropy of the Gamma-Ray from $C^{13}(p, \gamma\ p')C^{12}$.* H. HUGH WOODBURY, *Kellogg Radiation Laboratory, California Institute of Technology.*—A ten-channel differential discriminator has been built and employed with a scintillation counter to investigate the gamma-ray from $C^{12}(p, \gamma p')C^{12}$ which has been previously reported.[1] In addition to confirming the reported observations made at 90° with the incident proton beam, it has been found that the radiation at 0° is considerably weaker. Excitation curves at 90° and 0° will be given and discussed.

* This work was assisted by the joint program of the ONR and AEC.
[1] Tollestrup, Day, and Woodbury, Phys. Rev. **85**, 760 (1952).

F8. Gamma-Rays from $C^{13}+D^2$.* R. J. MACKIN, JR.,† *Kellogg Radiation Laboratory, California Institute of Technology.*—Secondary electrons from γ-radiation produced by 2.4-Mev deuterons on carbon have been observed with a magnetic lens spectrometer using 1.9-percent resolution. Compton spectra from 17 mg/cm² graphite corresponding to γ-rays of 3.67 ± 0.04 and 3.83 ± 0.04 Mev have been observed. The intensity ratio is 5/4 and the combined intensity is 1/5 that of the well-known 3.1-Mev γ-ray. These lines are probably associated with the 3.68 and 3.88 levels of C^{13} indicated by proton groups[1] from $C^{12}(dp)C^{13}$. Photoelectrons from a thorium converter reveal a γ-ray of 168 ± 1 kev. It has been established that this line does not come from $C^{13}+D^2$, and its excitation curve indicates a threshold near 1.7 Mev, consistent with its interpretation as a transition between the C^{13} levels mentioned above.

* Assisted by the joint program of the ONR and AEC.
† National Science Foundation Fellow.
[1] J. Rotblat, Phys. Rev. **83**, 1271 (1951).

F9. The Beta-Decay of F^{17} and F^{20}.* CALVIN WONG, *Kellogg Radiation Laboratory, California Institute of Technology.*—The reactions $F^{17}(\beta^+)O^{17}$ and $F^{20}(\beta^-)Ne^{20}$ have been investigated using a magnetic lens spectrometer. The positron spectrum of F^{17} consists of one component of maximum energy 1.749 ± 0.006 Mev. A Fermi-Kurie plot yields a straight line from the end-point energy down to an energy of 500 kev. β-ray branching to the first excited state of O^{17} at 874 kev is estimated to be <1 percent of the ground state transition. This estimate is consistent with the failure in this experiment to observe any delayed γ-radiation other than the annihilation radiation. The ft value for the ground-state transition is 2420 seconds, while the minimum ft value for the excited state transition is $\sim2\times10^4$ seconds. The electron spectrum of F^{20} consists of one component of maximum energy 5.419 ± 0.010 Mev. The Fermi-Kurie plot is linear from the end-point energy down to an energy of 400 kev. The delayed γ-radiation spectrum also consists of one component of energy 1.627 ± 0.005 Mev. The intensity of this γ-radiation shows that the β-decay proceeds to an excited state of Ne^{20} at 1.627 ± 0.005 Mev. The ft value for the transition is 9.73×10^4 seconds.

* Assisted by the joint program of the ONR and AEC.

F10. The Coupling of Angular Momenta in Nuclear Reactions.* R. F. CHRISTY, *Kellogg Radiation Laboratory, California Institute of Technology.*—Seven nuclear reactions have been examined where the angular distribution of reaction products is not uniquely determined by knowledge of the total angular momenta of the various nuclear states involved. In these cases the result depends on the type of coupling of angular momentum vectors in the nucleus. In six of the seven, the experimental angular distribution is consistent with the assumption of Russell-Saunders coupling in the nucleus. In three of the seven, the experiments are consistent with the assumption that the bombarding particle brings a definite j in the reaction. Neither assumption is sufficient to explain the result in one reaction ($B^{11}+H^1$).

* Assisted by the joint program of the ONR and AEC.

F11. The Beta-Spectrum of S^{35} from $C_2H_5S^{35}H$ below 33 kev. G. J. PLAIN, H. L. MORRISON, P. H. PITKANEN, AND F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station, Inyokern.**—The S^{35} beta-spectrum was investigated for information bearing on the low energy cutoff (abstract I3 of the 1952 Denver meeting). Approximately 1400 low energy S^{35} beta-tracks were measured out of about 35 000 beta-tracks recorded. Trace quantities of S^{35} in labeled ethyl mercaptan[1] were used in a diffusion cloud chamber.[2] The data have been corrected for relative deficiencies at the longer ranges which arise from the finite radius of the camera field and the finite focal depth. The corrected data shows a low energy cutoff at 10 kev. To enable examination of the efficiency of the counting of short tracks, additional experiments similar to the above were carried out, using an additional small amount of tritiated water[3] in the cloud chamber. These experiments showed that our efficiency of counting for the data on S^{35} is very nearly 100 percent for energies of 10 kev and above. The published results of several other experimenters on C^{14} in $C^{14}O_2$ (gas in

counter[4]), on B^{210} in $B^{210}(CH_3)_3$ (cloud chamber[5]), on C^{14} in $BaC^{14}O_3$ and S^{35} in Na_2S^{35} (magnetic spectrometer[6]), and on B^{210} above (magnetic spectrometer[7]), all indicate the same general trend at low energies, though there is as yet no general quantitative accord.

* Post Office: China Lake, California.
[1] Obtained under Authorization No. 11695 of the USAEC.
[2] H. L. Morrison and G. J. Plain, Rev. Sci. Instr. **23**, 607 (1952).
[3] Obtained under Authorization No. 13838 of the USAEC.
[4] Angus, Cockcroft, and Curran, Phil. Mag. **40**, 522 (1949).
[5] A. Waltner and F. T. Rogers, Jr., Phys. Rev. **75**, 1445 (1949).
[6] Cook, Langer, and Price, Phys. Rev. **74**, 548 (1948).
[7] C. B. Madsen, Acta Jutlandica Aarsskrift for Aarhus Universitit **XV**, 1 (1942).

F12. Thin Target Studies of $B^{10}(\alpha, n)N^{13}$, N^{13}.* MARGUERITE ROGERS, F. K. ODENCRANTZ, AND G. J. PLAIN, *U. S., Naval Ordnance Test Station, Inyokern.**—Thin target studies have been made of the reaction $B^{10}(\alpha, n)N^{13}$, N^{13*} by means of the recoil proton tracks in Eastman NTA nuclear plates. The neutron spectrum has been measured for a number of incident alpha-particle energies between 3 and 5.3 Mev. Evidence for an excited level in the N^{13} nucleus has been obtained. Yield data will be presented, from which the existence of resonances may be inferred.

* Post Office: China Lake, California.

F13. The Effect of Cloud-Chamber Geometry on Beta-Ray Studies. PAUL H. PITKANEN, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.**—Experiments with a continuously operating cloud chamber on β-decay[1] have indicated the importance of determining the influence of chamber geometry on the observed distribution of tracks. The experimental set-up to which this analysis applies consists of a continuously operating chamber, cylindrical in shape, with a vertically mounted camera whose field of focus is also cylindrical. Formulas for the correction to the observed distribution are obtained under a number of simplifying assumptions, the most important of which are: (1) the tracks are considered to be straight; (2) the depth and area corrections are assumed to be statistically independent. The limitations imposed by these assumptions are discussed.

* Post Office: China Lake, California.
[1] Plain, Morrison, Pitkanen, and Rogers, Jr. (see abstract, this meeting).

F14. Electron Positron Scattering. H. A. HOWE AND K. R. MACKENZIE, *University of California at Los Angeles.*—The ratio of electron to positron scattering on atomic electrons was determined. A single lens beta-spectrometer was used to select positive or negative beta-particles of one energy and to focus them on a scattering foil. Beyond the foil the scattering and scattered particles were counted in coincidence by two scintillation counters located in conjugate positions for a symmetric scattering event. By changing from an electron to a positron source and reversing the current in the spectrometer, almost identical scattering conditions were obtained and the ratio of electron-electron to electron-positron scattering was found for 1.3-Mev incident particles. Using the scattering cross section as predicted by Moller for the electron-electron case, and the Bhabha formula, with exchange, for the electron-positron case, the experimental ratio was 1.87 ± 0.11 as compared with the theoretical ratio of 1.83. If the electron-positron scattering is calculated without exchange, the experimental ratio differs from the theoretical ratio by approximately 35 percent. Therefore, the experiment definitely favors the inclusion of exchange effects in the calculation.

MONDAY AFTERNOON AT 1:30

Room 155, Arms

(A. H. WARNER presiding)

Contributed Papers

G1. Annealing Effects in Irradiated Copper.* ALBERT W. OVERHAUSER, *Department of Physics, University of Illinois.*—Copper wires were bombarded with 12-Mev deuterons at a temperature of $-180°C$. A total flux of $1.1 \cdot 10^{17}$ deuterons/cm^2 caused an increase in electrical resistivity of $7.8 \cdot 10^{-8}$ ohm-cm. The wires were then allowed to anneal isothermally at successive temperatures from $-185°C$ to $167°C$. Recovery of the resistivity was observed at all temperatures. The annealing curves obtained for temperatures between $-185°C$ and $-60°C$ were of such a character that only a number of processes with varying activation energies could account for them. One-half of the increased resistivity recovered in this range, and the activation energy appropriate for processes occurring at a given temperature, was proportional to the absolute temperature. Recovery near $-100°C$ was characterized by an activation energy of 0.44 ev. Above $-60°C$ the annealing took on a unique behavior that could be described as a simple process with a single activation energy. The shapes of the recovery curves in this region were close to those that would be expected of a binary process, and therefore suggest that recombination of the interstitial atoms and vacancies, produced by the bombardment, occurs at these temperatures. This process accounted for 25 percent of the increased resistivity and had an activation energy of 0.68 ev. At room temperature 25 percent of the increased resistivity remained, and further anneals to temperatures as high as 167°C produced only an additional 4 percent recovery.

* This work was supported by the AEC.

G2. The Effect of Quench Temperature and Cold Work on the Ordering Rates of Cu_3Au and CuAu.* C. E. DIXON AND C. J. MEECHAN, *North American Aviation, Inc., Atomic Energy Research Department, Downey, California.*—The initial ordering rate of Cu_3Au at 200°C and the amount of ordering which occurs in one hour has been found to increase, with increasing quench temperature, and to decrease if the alloy is very slightly cold worked. Cu_3Au foils were quenched in water from temperatures above the critical temperature. The ordering rate was determined by resistivity measurements made at liquid nitrogen temperature after pulse annealing at 200°C. Specimens quenched from 600°C decreased 4.5 ohm-cm in one hour, whereas the ones quenched from 450°C decreased only 1.9 ohm-cm in the same time. Specimens which had been plastically bent to a radius of 0.3 inch after the quench decreased 1.6 and 0.5 ohm-cm for the 600°C and 450°C quenches, respectively. In CuAu the ordering rate at 150°C is also sensitive to the quench temperature but less sensitive than Cu_3Au to small amounts of cold work. CuAu will order partially at room temperature; the rate is accelerated by very severe plastic deformation and is proportional to the amount of deformation. CuAu wires cooled in air were

cold worked by twisting in liquid nitrogen and pulse annealed at room temperature. The most severely cold-worked specimen showed a decrease of 0.43 ohm-cm after 144 hours while the strain-free standard decreased 0.02 ohm-cm.

* This work is based on studies conducted for the AEC.

G3. Quenched Vacancies in AuCu and $AuCu_3$.* J. BRINKMAN, *North American Aviation, Inc., Atomic Energy Research Dept., Downey, California.*—It has been observed that the initial rate of approach to the ordered state of the disordered alloys, AuCu and $AuCu_3$ varies approximately as $\exp(-E_f/kT)$ with the temperature T, from which the alloy is quenched.[1,2] This is interpreted as an indication that the rate of ordering is proportional to the density of some lattice defect which exists in thermodynamic equilibrium at the high temperature and which can be frozen into the metal by a rapid quench. Seitz[3] has concluded that it should be possible to freeze in a non-equilibrium number of vacancies in copper. It is therefore suggested that the defects frozen into these alloys are vacancies, and that ordering occurs by their migration. If such is the case, E_f should be the energy of formation of vacancies in the alloy. Furthermore, it should be possible to measure the activation energy for migration of vacancies, E_m, by observing the dependence of the initial ordering rate on ordering temperature. An analysis of unpublished data[1,2] gives the following values for both AuCu and $AuCu_3$: $E=0.4\pm0.1$ ev; $E_m=1.2\pm0.15$ ev.

* This report is based on studies conducted for the AEC.
[1] C. E. Dixon, and C. J. Meechan (preceding abstract).
[2] P. G. Stello, North American Aviation Report: NAA-SR-171, 1952.
[3] F. Seitz, Acta Cryst. **3**, 355 (1950).

G4. Optical Effects of Radiation Damage in Alkali Halides.* DONALD R. WESTERVELT, *North American Aviation, Inc., Atomic Energy Research Dept., Downey, California.*—An absorption peak at 580 mμ has been reported in NaCl,[1] resulting from thermal treatment of electron-bombarded crystals. Similar bands have now been observed, both at room temperature and at liquid nitrogen temperature in electron-bombarded KCl, KBr, and KI, at various stages of thermal annealing. In each case after bombardment at room temperature with 1-Mev electrons, a latent absorption peak exists between the F and M bands, which develops rapidly when the damaged crystal is warmed, at the expense of the familiar electron-surplus bands. This radiation-damage band is bleached by further heating, the latter stages of the process proceeding by a first-order reaction. The case of KCl, in which the radiation-damage band can be identified with the "colloidal band" reported by Scott and Smith[2] is considered in detail.

* This report is based on studies conducted for the AEC.
[1] D. R. Westervelt, Phys. Rev. **86**, 643 (1952); see also a review by K. Przibram of recent work on crystals discolored naturally or by polonium alpha-particles, Z. Physik **130**, 269 (1951).
[2] A. B. Scott and W. A. Smith, J. Chem. Phys. **83**, 982 (1951).

G5. Annealing of Radiation Damage Effects in Copper.* R. R. EGGLESTON, *North American Aviation, Inc., Atomic Energy Research Dept., Downey, California.*—Copper specimens have been bombarded while being maintained at temperatures below −150°C with high energy alpha-particles using the University of California 60-inch cyclotron at the Crocker Laboratory in Berkeley. After the irradiation the specimens were annealed using a pulse annealing technique previously described.[1] A few specimens were given a tempering anneal at progressively higher temperatures while the others were isothermally annealed. Residual resistance was the observed physical parameter used to follow the annealing behavior in both cases. Tempering curves will be presented over the range of annealing temperature from −135°C to +105°C. Isothermal annealing curves at temperatures between −20°C and −65°C will also be presented. Analysis of these later curves yields an activation energy for the annealing process in this range of temperature of 14.9 kcal/mole.

* This report is based on studies conducted for the AEC.
[1] Parkins, Dienes, and Brown, J. Appl. Phys. **22**, 1012 (1951).

G6. The Influence of Cold Work and Radiation Damage on the Vibrational Spectra of Copper.* D. B. BOWEN AND G. W. RODEBACK, *North American Aviation, Inc., Atomic Energy Research Dept., Downey, California.*—The difference in Debye temperature between samples of well-annealed and cold-worked, or radiation-damaged copper wires has been measured. Simultaneous measurements of electrical resistance as a function of temperature are made on the annealed and the damaged samples. In this way the difference in the temperature dependent portion of their resistance can be observed directly and this difference fitted to a differential form of Gruneisen's equation to obtain directly the difference in Debye temperature between the samples. In each case the damaged lattice had a lower Debye temperature than the annealed one. The maximum changes are from twenty to forty degrees. The apparatus has a resolution in Debye temperature change of less than ½ degree. There is a small variation of the change with temperature of measurement. Results on the thermal annealing of these changes will be presented. An interpretation in terms of the vibrational spectra, and the associated thermodynamic implications will be discussed.

* This report is based on studies conducted for the AEC.

G7. Radiation-Damage Energy Threshold in a Face-Centered Cubic Alloy.* J. M. DENNEY, *North American Aviation, Inc., Atomic Energy Research Dept., Downey, California.*—It has been found that suitable treatment of an alloy of iron in copper (2.4 wgt. percent iron) induces an iron precipitate whose lattice is coherent with the copper lattice. Aging at an elevated temperature insures growth of the coherent iron precipitate to near the terminal precipitate size. Since the iron is in the face-centered cubic form, it is paramagnetic, and thus the specimen is paramagnetic. Upon transforming to the stable body-centered cubic structure, the iron becomes ferromagnetic. Measurement of the saturation magnetization of the alloy is, thus, a direct measure of the mol fraction of transformed iron. The introduction of Frenkel defects by bombarding thin foils with high energy particles will initiate the transformation of the face-centered cubic iron. Foils have been bombarded with electrons from an electron accelerator at varying energies. It has been found that a threshold energy of about 0.5 Mev exists, below which the iron does not transform upon bombardment with electrons. Suitable calculations indicate that this threshold in the beam energy is associated with the energy required to form a Frenkel defect by displacing an atom from the lattice. An upper limit to the displacement energy of 25±2 ev is thus obtained.

* This report is based on studies conducted for the AEC.

G8. The NAA Statitron as a Facility for Solid-State Research.* D. T. EGGEN AND H. KENWORTHY, *North American Aviation, Inc., Downey, California.*—A 2-Mev electron statitron was designed for radiation-damage experiments in solid state and radiation chemistry at the Atomic Energy Research Department of North American Aviation, Inc. In certain experiments, e.g., atomic displacement energy in crystals,[1] the energy is critical and a minimum amount of energy degradation is desired. It is necessary to irradiate the target in an extension of the accelerator tube vacuum system without passing through a window. Therefore, a high speed, large capacity vacuum system has been incorporated. In other experiments, e.g., the irradiation of alkali halide crystals for the production of F centers,[2] where the electron energy is less critical, or where a diffuse beam is required, the electrons are brought out of the accelerator tube through a window. Where

the target must be maintained in a vacuum, but where the vapor pressure is too high to be incorporated in the accelerator tube system, a window is placed between the irradiation cell attached beneath the accelerator tube, e.g., irradiation chemistry experiments on organic or liquid samples.[3] The energy of the machine has been calibrated using the Be(γ, n) at 1.667 Mev. The beam current is collected through an electronic integrating circuit and is calibrated by a calorimetric method.

* This work was performed under AEC contract.
[1] M. M. Mills, "Estimated values of electron threshold energies necessary for atomic displacements" (private communication).
[2] Westervelt, "Optical Effects of Radiation Damage on Alkali Halides," (see abstract, this meeting).
[3] Feldman, Ruebsamen, and Shon, "Radiation Chemistry of Organic Materials. I. Biphenyl," (unpublished work at North American Aviation).

G9. Treatment of the Defect Relaxation Time of Conduction Electrons in Crystals by the Tight Binding Approximation.* J. LOMONT, *North American Aviation, Inc.,† Atomic Energy Research Dept., Downey, California.*—The Bloch 1-electron approximation and the Boltzmann equation are assumed. A relaxation time $\tau(\mathbf{k})$ is defined in terms of the distribution function, and a new linear integral equation for τ is derived by letting the external field vanish. A field dependent term does not appear to vanish from the equation. If it actually does not, then the Boltzmann equation should be critically re-examined. Using the perturbation formula (in the special case of scattering by point defects) for the transition probability appearing in the equation for $\tau(\mathbf{k})$, and using the tight binding approximation form of the electronic wave function (so as to avoid the free-electron assumption), one can calculate the explicit form of the $\mathbf{k}$ dependence of the transition probability without specifying either the ionic potentials or the atomic orbitals. The result involves unspecified coefficients which depend on the type of defect considered. The $\mathbf{k}$ dependence of the relaxation time can then be found by solving the linear integral equation for it. This has been carried out for the two-dimensional model of graphite.

* J. S. Lomont, NAA-SR-205 (1952). This report is based on studies conducted for the AEC.
† Now at USNOTS, China Lake, California.

G10. Observation of Magnetic Domains by the Longitudinal Kerr Effect.* C. A. FOWLER, JR., AND E. M. FRYER, *Pomona College.*—Both the polar and the longitudinal Kerr magneto-optic effects have been recently employed with success to observe ferromagnetic domain patterns, the polar effect at normal incidence for hexagonal cobalt cut to expose free surface poles,[1] and the longitudinal effect at oblique incidence for the (100) surface of a large slab-shaped single crystal of silicon iron.[2] In the latter case at 60° incidence, the rotation of approximately 4 minutes to right or left by the adjacent antiparallel domains is enough to reveal the domains with considerable contrast when photographed through an analyzer set near extinction. A comparison of the front and back (100) faces of the demagnetized crystal shows the domain patterns to be essentially identical but oppositely directed, suggesting flux closure. A series of photographs, taken as the sample is carried through an initial magnetization curve to saturation, clearly shows the characteristic movement of domain walls. When the specimen is taken through a hysteresis cycle, the pattern of surface domains, as the sample departs from the condition of saturation, differs markedly from the pattern observed in the initial magnetization curve.

* Supported by the ONR.
[1] Williams, Foster, and Wood, Phys. Rev. **82**, 119 (1951).
[2] Fowler and Fryer, Phys. Rev. **86** 426 (1952).

G11. Flash Radiographic Studies of High Velocity Metallic Jets. LOUIS ZERNOW, *Terminal Ballistics Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland.*—Recent improvements in the techniques of ultra high speed flash radiography will be described, including a new low voltage system for obtaining three successive radiographs of the same event. The application of this system to the study of the basic physics of high velocity jets (23,000 feet/second) from large-scale shaped charges will be illustrated with radiographs comparing the behavior of jets from a variety of metallic liners. The direct measurement of the velocity gradient along a jet by means of multiple flashes from the same x-ray tube will also be illustrated.

G12. Measurement of Heat of Dissociation of Fluorine by the Effusion Method.* HENRY WISE, *Jet Propulsion Laboratory, California Institute of Technology.*—A wide range of values have been reported[1] for the energy of dissociation of the fluorine molecule. Estimates of this fundamental physical parameter based on the long-wave limit of the continuous absorption spectrum show wide disagreement with those obtained by thermochemical considerations for the ClF molecule and the measurement of the equilibrium pressure of F_2 at elevated temperatures.[2] For a direct determination of the heat of dissociation of fluorine, the gas effusion method[3] is particularly suitable since the experimental measurements are carried out at low pressures (molecular-flow region), and, therefore, a measurable degree of dissociation is attained at relatively low temperatures. The apparatus described in this paper consisted of a nickel tube housing a thin-edged circular orifice (0.185 mm in diameter) made of the same material. From the variation in the rate of gas effusion over the temperature range from 500 to 800°K at a total pressure of 4×10^{-4} mm Hg, the heat of reaction for the process $F_2(g) = 2F(g)$ was found to be 37.6 ± 0.8 kcal/mole. The results tend to confirm the dissociation energy calculated from thermochemical data,[4] which are based on the heat of formation of ClF of 11.6 kcal/mole. They are also in good agreement with the data reported in the direct measurement of the pressure variation with temperature.[5]

* This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory under U. S. Army Ordnance Department contract.
[1] Haar and Beckett, Natl. Bur. Standards Rept. No. 1435 (Feb. 1, 1952).
[2] R. N. Doescher, J. Chem. Phys. **19**, 1070 (1951).
[3] M. Knudsen, Ann. Physik **29**, 179 (1909).
[4] Eucken and Wicke, Naturwiss. **10**, 233 (1950).

MONDAY AFTERNOON AT 1:30

Room 119, Kerchoff

(J. KAPLAN presiding)

Contributed Papers

H1. New Fine Structure in Oxygen OI.* LEE W. PARKER AND JOHN R. HOLMES, *University of Southern California.*—During a recent investigation of isotope shifts in oxygen,[1] untabulated fine structure was resolved in the triplet multiplets λ8446 ($3s\,^5S_1 - 3p\,^5P_{210}$), λ2884 ($3p\,^5P_{21} - 3d'\,^5P_3$), and λ4368 ($3s\,^5S_1 - 4p\,^5P_{210}$). Interferometer patterns of these lines were analyzed to obtain splittings and relative intensities. Listed as a doublet, λ8446 has three components whose

relative intensities allowed establishment of the $3p\,^3P_{210}$ anomalous splitting as follows: $J=1$ lies 0.599 ($\pm$0.003) cm^{-1} below $J=2$, and $J=0$ lies 0.158 ($\pm$0.002) cm^{-1} above $J=2$, in close agreement with Edlén[2] and with Davis and Meissner.[3] λ2884, heretofore found single, has two components, separated by 0.558 ($\pm$0.002) cm^{-1}. Two components of λ4368, previously considered single, were resolved and have a separation of 0.300 ($\pm$0.001) cm^{-1}, the weaker component having the shorter wavelength. From the relative intensities it is deduced that $J=0$ lies above the degenerate $J=2$, 1 level of the state $4p\,^3P_{210}$, which, like $3p\,^3P_{210}$, is perturbed by an unobserved state in the displaced (^3D) system.[3]

* Supported by the ONR.
[1] Lee W. Parker and John R. Holmes, Phys. Rev. **88**, 174 (1952).
[2] Edlén, Kingle. Svenska Vetenskapsakademiens Handlingar, Ser. 3, Vol. 20, No. 10 (1943).
[3] λ8446 reported by D. O. Davis and K. W. Meissner, J. Opt. Soc. Am. **42**, 871 (1952).

H2. Preliminary Results of Direct Measurements of Photoionization in O_2.* N. WAINFAN AND W. C. WALKER, *University of Southern California* (introduced by G. L. Weissler).—By using a vacuum spectrograph as a monochromator, radiation from a constant high intensity light source was passed through an exit slit into a chamber which contains the gas at low pressures. Two low voltage ionization chambers in tandem were used to determine ion currents and thereby total absorption coefficients in the gas. In order to measure the photon flux through the exit slit, a sensitized 1P28 photomultiplier was used. The output of the 1P28 was correlated with the signal from a calibrated thermopile. In the range from 1080A to 450A the absorption coefficients were substantially the same as those reported previously.[1] Measurements of the number of ions per absorbed photon indicated that between 1080A and 850A the fraction of the total absorption which was accounted for by photo-ionization processes rose monotonically from about 0.3 to 1.0. Below 850A the absorption mechanism appears to be entirely due to photo-ionization. Work is now underway in other gases, including neon and nitrogen.

* The aid of the ONR is gratefully acknowledged.
[1] G. L. Weissler and Po Lee, J. Opt. Soc. Am. **42**, 200 (1952).

H3. The Photoelectric Yield of Platinum in the Vacuum Ultraviolet.* W. C. WALKER AND N. WAINFAN, *University of Southern California* (introduced by G. L. Weissler).—Preliminary values of the quantum yields of Pt between 1100A and 450A were obtained using a plane Pt photocathode and a Pt ring collector. A vacuum monochromator together with a photomultiplier calibrated in terms of photons per second, using the same experimental arrangement as described in a concurrent abstract by the same authors, was used in this work. The yields, expressed as the ratio of the number of photoelectrons to the number of photons, were measured for both an untreated Pt surface and the same one heated to about 1000°C. Values obtained for the untreated surface were about 20 percent larger than for the other. The results indicated a maximum yield in both cases at about 800A, with a value of 0.16 electron/photon for the heated sample at this wavelength. To either side of this maximum the ratios decreased monotonically to 0.04 at 1100A and 0.08 at 450A for the heated surface. These results agree well with those obtained by Hinteregger.[1] Data will also be presented on Ni, Ta, and other metal surfaces.

* The aid of the OOR is gratefully acknowledged.
[1] H. E. Hinteregger and K. Watanabe, Cambridge Air Force Research Center (private communication) (June, 1952).

H4. The Absorption Cross Sections of CH_4 in the Vacuum Ultraviolet. G. L. WEISSLER* AND H. SUN, *University of Southern California.*—Absolute absorption coefficients k_ν of CH_4 for extreme ultraviolet radiation were measured between 1300A and 510A for 82 wavelengths. At 1300A, $k_\nu=400$ cm^{-1}. The absorption rises to a peaked maximum of $k_\nu=1500$ cm^{-1} or $\sigma=5.6\times10^{-17}$ cm^2 at 960$\pm$20A. This wavelength corresponds to 12.9$\pm$0.2 ev and is identified as the first ionization potential of CH_4 which has been measured recently[1] to be about 13.1 ev k_ν decreases gradually to 650 cm^{-1} at 510A. The measured cross section σ at the maximum is smaller than the theoretical value of Dalgarno,[2] 9.4×10^{-17} cm^2, which was based on the method of self consistent field with exchange effects neglected. The pronounced rise of the absorption contour at 960A supports the application of a quasi-atomic model to CH. However, the existence of continuous absorption at wavelengths longer than the ionization limit perhaps points to limitations of this model. The integrated experimental cross sections between 1300A and 510A yield an f value of about 6 compared to 6.3 from theory[2] between 946A and 500A.

* The aid of the ONR is gratefully acknowledged.
[1] Lossing, Tickner, and Bryce, J. Chem. Phys. **19**, 1254 (1951).
[2] A. Dalgarno, Proc. Phys. Soc. (London) **A65**, 663 (1952).

H5. Further Results on Neon and Argon Absorption in the Extreme Ultraviolet. PO LEE AND G. L. WEISSLER,* *University of Southern California.*—Absorption of neon[1] and argon was measured between 1300A and 250A by photometric methods. Some sharp absorption edges were found corresponding to the L_1, L_2 and M_1, M_2 levels of neon and argon, respectively. For neon and ionization continuum began at 574.9A (L_2) with an absorption coefficient of $k_\nu=146\pm8$ cm^{-1} or $\sigma_\nu=5.5\pm0.3\times10^{-18}$ cm^2. The theoretical values of Seaton[2] using a dipole length and a dipole velocity approximation were $\sigma_l=5.8\times10^{-18}$ cm^2 and $\sigma_v=4.4\times10^{-18}$ cm^2, respectively. The second absorption edge (L_1) appeared at about 255A with $k_\nu=162$ cm^{-1}. The region between 575A and 380A showed results which agreed well with those calculated from the dipole length approximation.[2] Preliminary argon work showed $k_\nu=515$ cm^{-1} at 780A (M_2 edge at 786A), $k_\nu=960$ cm^{-1} at 776A (M_2 edge at 778A), and $k_\nu=270$ cm^{-1} at 418A (M_1 edge at 424A). A photo-ionization cross section at the M_2 edge was estimated to be $\sigma=3.4\pm0.3\times10^{-17}$ cm^2, compared to the theoretical one[3] of $\sigma=3\times10^{-17}$ cm^2.

* The aid of the ONR and the Cambridge Air Force Research Center is gratefully acknowledged.
[1] Improved over previous work by Po Lee and G. L. Weissler, J. Opt. Soc. Am. **42**, 214 (1952).
[2] M. J. Seaton, Proc. Roy. Soc. (London) **A208**, 408 (1951).
[3] A. Dalgarno, Proc. Phys. Soc. (London) **A65**, 663 (1952).

H6. A Multicolor Photoelectric Photometer for Study of Faint Radiations. D. R. WILLIAMS AND PIERRE ST. AMAND, *U. S. Naval Ordnance Test Station, Inyokern.**—An improved, greatly modified version of the Marlow-Pemberton night sky photometer is described. Direct current amplifiers are employed. Separate telescopes, multiplier phototubes, amplifiers and recorders are used for each wavelength region observed.

* Post Office: China Lake, California.

H7. The ν_1 Band of D_2O in the Infrared. W. S. BENEDICT, *The Johns Hopkins University,* AND NORMAN GAILAR AND EARLE K. PLYLER, *National Bureau of Standards.*—We have been measuring with higher resolution the infrared absorption of D_2O and HDO. Quite complete rotational analyses of 7 bands of D_2O and 7 bands of HDO have been achieved, permitting determination of consistent sets of vibrational and rotational constants. The present report will discuss ν_1, the symmetric stretching vibration of D_2O, previously observed only in the Raman effect, which appears with good intensity in the region 2400–2900 cm^{-1}. It is quite free of overlapping from lines of the asymmetric stretching frequency ν_3 in the region below 2600 cm^{-1}, permitting complete identification of the P branches out to $JK_a=10_6$. The band origin is at 2671.7 cm^{-1}, and the inertial constants are $A=15.12$, $B=7.14$, $C=4.75$ cm^{-1}. In contrast with the corresponding bands in H_2O, where the intensity ratio $\nu_1:\nu_3$ is about 1:15, ν_1 is rather

strong, the ratio in D_2O being about 1:3. Coriolis interaction between ν_1 and ν_3 is very weak, as evidenced by only minor perturbations of the ν_1 levels with $K_a=6$ and 7, whose position coincides closely with $K_a=5$ and 6 of ν_3.

H8. Flame Zone Spectroscopy of Solid Propellants. R. G. REKERS AND D. S. VILLARS, *U S. Naval Ordnance Test Station, Inyokern.**—The spectroscopy of burning solid propellants has been generally limited to a photographic integration of the various flame zones as the burning strand is consumed and the flame passes a spectrographic slit. A few instances have been reported in which separation of the spectral emission from the different zones of the flame has been attempted, but the results are deficient either through loss of resolution of the spectrograph system or shortness of exposure time. An automatic constant level device is reported which now permits the isolation and detailed exposure of a definite flame zone throughout the complete time of burning of a 72-inch length of strand. A discussion of the technique, illustrated with typical data on the degree of control, will be presented. Also described will be results of an exploratory spectrographic study, involving both absorption in the nonluminous regions of burning and emission in the luminous zone.

* Post Office: China Lake, California.

H9. A Possible Relationship Between the Ionosphere and the Nightglow. PIERRE ST. AMAND AND D. R. WILLIAMS, *U. S. Naval Ordnance Test Station, Inyokern.**—The nocturnal variation of the λλ6300, 6364[OI] radiation resembles that of the number of ions in the *F* region of the ionosphere. The possibility that the two phenomena may be related is discussed.

* Post Office: China Lake, California.

H10. The Height of Upper Atmosphere Emissions by the Van Rhÿn Method. F. E. ROACH, HELEN B. PETTIT, D. R. WILLIAMS, AND P. ST. AMAND, *U. S. Naval Ordnance Test Station, Inyokern.**—A critical study is made of the various problems involved in estimating the heights to nightglow emissions by the Van Rhÿn method. In particular the amount of integrated starlight and zodiacal light included as background in photometric observations is considered. A detailed analysis of several nights of observation in four colors at Cactus Peak is given.

* Post Office: China Lake, California.

H11. A Short Afterglow in Nitrogen.* W. B. KUNKEL, *University of California, Berkeley.*—A powerful rf glow discharge was used to excite intense afterglows in a large flow system at pressures ranging from 0.5 to 10 mm Hg. In addition to the well-known Lewis-Rayleigh afterglow, an extremely bright luminosity of about 0.1 second visible life was produced in pure nitrogen. Its spectrum consisted of the first positive group appearing in the same form as in the discharge itself and of the bands of molecular ions. The latter were completely suppressed when about 0.1 percent oxygen was added to the stream. Similar short glows have been observed by Kaplan[1] and by Herman[2] in pulsed systems containing electrodes. While it has been suggested[2] that the radiation may be due to electron-ion recombination it seems more likely that transitions from metastable singlet states are responsible for the population of the $\beta^3\pi_g$ state as suggested by Nicholls.[3] Moreover, strong continued selfionization of the gas by collisions between excited particles, possibly involving the $\alpha^1\pi_g$ state, is indicated.

* Supported by the Wright Air Development Center.
[1] J. Kaplan, Phys. Rev. **42**, 807 (1932).
[2] R. Herman, Compt. rend. **220**, 593 (1945).
[3] R. W. Nicholls, Nature **162**, 231 (1948).

H12. Effects of Hydrogen Bonding on the Infrared Spectra of Alcohols. ALEXANDER VERRIJN STUART* AND G. B. B. M. SUTHERLAND, *University of Michigan.*—In order to clarify the nature of the hydrogen bond, spectra have been studied of various series of alcohols under different conditions, between 6μ and 25μ, using the well-known effect on the OH stretching vibration in the 3μ region as a guide. The results are complex, and seem to depend on the nature of the alcohol (primary or secondary) and on the position of substituents in the hydrocarbon part of the molecule. Instead of the expected two "association" bands (due to the in-plane and out-of-plane OH deformation vibrations), one finds, in general, four such bands, *viz.*, at about 7.1, 7.5, 9.0, and 15.0μ. The latter is very constant and resembles the wide association band for the OH stretching. One may identify it with the out-of-plane OH motion. In CH_3OD an association band of the same character is found at 21μ, supporting the assignment to an OH (OD) vibration. The other bands are rather irregular, and the single "monomer" band found in dilute solutions at about 8.2μ is extremely variable in position. Possible interpretations of all these results will be discussed.

* Now with Koninklijke/Shell-Laboratorium, Amsterdam, Netherlands.

H13. The Measurement of Light Scattered from a Searchlight Beam. E. V. ASHBURN, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.**—A recording photoelectric photometer has been designed which will separate the light that is scattered from a searchlight beam from the background light of the night sky, without the necessity of modulating the beam. The polarization of the scattered light is used to separate the light from the two sources. The measurement of the intensity of the light scattered from the searchlight beam is used to determine the density in the stratosphere at heights inaccessible by balloons.

* Post Office: China Lake, California.

MONDAY AFTERNOON AT 1:30

Room 22, Crellin

(L. B. LOEB presiding)

Contributed Papers

I1. Harmonic Analyses of Pulses and Spectral Analyses of Transients. S. LEROY BROWN AND JOHN M. NORWOOD, *University of Texas.*—Each quarter of a wave may be analyzed as a repeating pulse which has values of zero over the remaining three-fourths of its repetition period. This permits fifteen ordinates to be taken for each quarter-wave, or sixty ordinates for the entire wave, and thereby twenty-nine harmonics are determined. The analyses of the four quarter-wave pulses may then be combined, and thereby the wave is analyzed for fifty-eight Fourier coefficients (twenty-nine cosine terms and

twenty-nine sine terms). The approximate integration for the values of fifteen ordinates is done for each quarter-wave with a mechanical harmonic synthesizer with fifteen harmonic components. The spectral analysis of a transient is determined from thirty equispaced ordinates, the origin at the middle of the transient with fifteen equispaced ordinates on either side. The fifteen sums of pairs of ordinates symmetrical with the origin are set on the respective cosine elements of the synthesizer, and a trace is obtained which shows the distribution of the cosine components throughout the spectrum of the transient. Similarly, fifteen differences of the pairs of ordinates are set on the sine elements and the resulting trace is the spectral distribution of sine components.

I2. Variational Approach to a Theory for the Critical Stability of a Fluid. II. F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station, Inyokern, California.*—We have succeeded in reformulating, and giving an approximate solution to, the problem identified in reference 1, for the case $\varphi > 0$. The reformulation incorporates Morrison's recent observations[2] as to patterns of flow when critical stability has been passed. This approximate solution is in accord with all published experimental data, to within a random factor of about 3, which probably represents experimental uncertainties. We wish to suggest that these findings may bear upon certain matters pointed out by Summerfield,[3] inasmuch as the establishment of flow (by passage beyond critical stability) involves the concommitant establishment of the three-dimensional laminar boundary layer of great extent.

[1] F. T. Rogers, Phys. Rev. **85**, 770 (1952).
[2] H. L. Morrison and F. T. Rogers, J. Appl. Phys. **23**, 1858 (1952).
[3] M. Summerfield, J. Am. Rocket Soc. 85, June 1950.

I3. Drag on a Rotating Cylinder at Low Pressures.* S. F. CHIANG AND S. A. SCHAAF, *University of California, Berkeley.*—The torque transmitted by a rarefied laminar air flow between two concentric cylinders, of which the inner one is rotating, was determined for a range of pressures extending from free molecule to continuum flow. The range covered in terms of Mach number M, Reynolds number Re and the Knudsen number K (ratio of mean free path to gap width) was $0.14 < M < 0.55$, $0.054 < Re < 50$, $0.018 < K < 3.9$. The theoretical predictions based on, respectively, (a) the Navier-Stokes equations and the first-order slip boundary condition, (b) the Burnett equations and a second-order slip flow boundary condition, and (c) the 13-moment equations and boundary conditions of H_{grad} all agree with each other and with the experimental results within ± 1 percent in that part of the slip flow range $(0.01 < K < 0.1)$ covered by the experiments. The first theory agrees with the experiments over the entire range covered.

* This work was jointly supported by the ONR and OSR.

I4. Sputtering in the High Vacuum and its Relation to Radiation Damage as Described by Seitz. FRANK KEYWELL, *University of Southern California.*—The Seitz radiation damage theory[1] is introduced with reference to other experimental work which verifies the ideas involved. It is argued that radiation damage will persist to low energies; thus one should expect energetic gaseous ions striking a metal surface to produce this effect (commonly called "sputtering"). Comparison is made between the number of atoms displaced in a metallic lattice according to Seitz' theory and the number of atoms sputtered for an ion of given energy E_0 incident in a metal surface. Neutron cooling theory is applied to the process for heavier ions.[2] The effect of absorption is present, as expected, and can be roughly treated only for the heavier ions. In all cases, the number of atoms sputtered n_a is less than the number of atoms displaced N. The curves of N *vs* E_0 have the same form as n_a *vs* E_0 for the gas-metal combinations studied by use of a P.I.G. ion source. Data have been obtained for A−Ag, Ne−Ag, He−Ag, and He−Pb over a range of ~500–5000 volts. Inclusion of the effect of absorption gives close agreement between theory and observation for the A−Ag and Ne−Ag cases. Experimental sputtering thresholds agree favorably with those estimated by collision theory. An explanation is given for the nonsputtering of metals bombarded by electrons of medium energy.

[1] Frederick Seitz, Disc. Faraday Soc. **271** (1949).
[2] Frank Keywell, Phys. Rev. **87**, 160 (1952).

I5. Evaluation of Back Diffusion for Various Standard Gases as it Affects Secondary Electron Emission Coefficients.* J. K. THEOBALD, *University of California, Berkeley* (introduced by Leonard B. Loeb).—The effect of back diffusion of photoelectrons was measured in clean molecular and inert gases for two energy distributions of the electrons, and the results were applied to the analysis of the Thomson equation as an empirical formula for correcting the measurements of the secondary emission coefficients in gaseous discharges. The effect of electron attachment to oxygen molecules to form negative ions is found to be negligible at low current densities, in agreement with a theory due to Loeb and Kunkel. Back diffusion is found to depend on the ratio of field strength to pressure and the initial energy of emission, as expressed by the Loeb modification of Thomson's theory. This theory is believed to hold within a factor of 5 in the most doubtful cases, and agrees with experiment surprisingly well when the initial energy of emission and the random energy of the electrons after reaching equilibrium with the field are nearly the same. After correcting for back diffusive loss, the γ-values obtained by Lauer[1] agree satisfactorily with those of Molnar.[2]

*This work was supported by the ONR.
[1] E. J. Lauer, J. Appl. Phys. **23**, 300 (1952).
[2] J. P. Molnar, Phys. Rev. **83**, 933 (1951).

I6. The Influence of an Electric Field in Contact Charging.* JOHN W. PETERSON, *Department of Physics, University of California, Berkeley* (introduced by L. B. Loeb).—Recent experiments have indicated that the charging of nonconductors in smooth rolling contact with a metal is determined by the surface conductivity of the nonconductor, speed of rolling, equivalent of a contact potential difference between the nonconductor and the metal, pressure and nature of the atmosphere in which charging takes place, and the presence of an external electric field. Small Pyrex glass spheres rolling on nickel were used. Reduced pressures increases discharge by sparking. In the case of low surface conductivity, surface charge due to polarization of the dielectric spheres is readily measurable. Surface conductivity increases on admitting water vapor to a determined pressure, thus increasing the adsorbed water layer on the surface of the spheres. The increasing surface conductivity results in an increasing effect of the electric field, together with decreased charging in zero field. At about 55 percent relative humidity at 20°C the usual negative charge of the glass spheres can be reversed by the applied electric field, and above 60 percent relative humidity the spheres become essentially conducting.

* This study has been supported by the ONR.

I7. Vacuum Sputtering of Metallic Sodium by Inert Gas Ions.* RICHARD C. BRADLEY, *University of California, Berkeley.*—A new technique for studying the sputtering of metals by positive ion bombardment under vacuum conditions is developed. With this method metals to be sputtered are limited to the alkalis, and sputtered atoms are detected by a surface ionization detector consisting of a hot platinum foil partially surrounded by a collector plate. This yields a direct measurement of the number of atoms being sputtered into a given solid angle determined by sizes of target and detector and their relative positions. The sodium target was prepared by distilling the sodium through four stages under high

vacuum, flowing it into the target position while liquid, and allowing it to cool. Renewal of the surface is effected by reliquifying the sodium and overflowing the old target. Preliminary measurements of sputtering rates *versus* ion energy have been made, using a monochromatic beam of ions of argon, neon, and helium extracted from a Phillips Ion Gauge ion source collimated into a beam by an ion gun. The energy range covered was 25 volts to 1500 volts. The secondary electron coefficient for ion bombardment of sodium has also been measured in this same range of ion energies.

* This work was supported by the ONR.

I8. Secondary Cathode Action in N_2 with Coaxial Cylindrical Geometry.* ELSA HUBER, *Department of Physics, University of California, Berkeley.*—A study is being made of the breakdown processes in nitrogen at pressures ranging from 10- to 600-mm Hg. The discharge takes place between a platinum wire at a positive potential and a coaxial nickel cylinder and is triggered by individual α-particles sent through the gap parallel to the wire. The resulting pulses are viewed on an oscilloscope. In the purest nitrogen used to date (as indicated by mass spectrometer analysis) there is a γ_i effect, due to secondary electron liberation at the cathode by positive ions, but no observable γ_p from secondary electron liberation by photoelectrons. If the nitrogen is slightly contaminated, however, a γ_p does become apparent, and at the same time the γ_i secondary pulses become less pronounced. It is believed this change is associated with the presence of oxygen. There is some evidence that two types of nitrogen ions are involved, probably N_2^+ and N_4^+.

* This study has been supported by the ONR.

I9. Secondary Electron Emission Coefficients for Low Energy Positive Ion Bombardment of Discharge Conditioned Surfaces.* JAMES H. PARKER, *Department of Physics, University of California, Berkeley* (introduced by Leonard B. Loeb).—The vacuum secondary electron yield due to A^+ ions, i.e., γ_i, has been measured for discharge conditioned Ta, Pt, and Ni surfaces. Discharge conditioning consists of operating the surfaces at the cathode in a heavy dc glow discharge of N_2, H_2, or O_2. The range of argon ion energy over which γ_i has been determined is 3–200 ev. The spread in ion energy for this range is 2 ev. The argon ions are obtained from a Heil[1] or Finkelstein[2] ion source operating at 10^{-3} mm Hg in argon. The source and target are at the same pressure, which is low enough for large A^+ mean free paths. The targets are in the form of thin sheet (<0.001 inch) and can be outgassed by conduction current through them. The electrode assembly, which is of tantalum sheet encased in Pyrex, can be thoroughly baked and electrodes outgassed by induction heating.

* This study has been supported by the ONR.

[1] Heil, Z. Physik 120, 212 (1944).
[2] A. I. Finkelstein, Rev. Sci. Instr. 11, 44 (1940).

I10. Pre-Onset Burst Pulses in Positive Point to Plane Corona in Air.* M. R. AMIN, *Department of Physics, University of California, Berkeley.*—Mechanism of corona discharges in point to plane geometry in room air at atmospheric pressure have been investigated by the use of a photomultiplier. The correlation of the photon pulses with the induced pulses observed through a series resistor have revealed new information as to the nature of burst pulses. The burst pulse seems to consist of an initial pulse spreading over the point in less than 10^{-7} second and followed by secondary pulses each of the same duration but with smaller amplitude. The dead time just before onset is of the order of 5 to 10 microseconds and the clearing time for the whole burst is of the order of milliseconds. The number of ions in the initial pulse is of the order of 10^7 ions and in the secondary pulses of the order of 10^8 ions. These findings definitely indicate the pre-onset burst pulse corona to be a typical Geiger counter mechanism, operating at atmospheric pressure and somewhat different conditions from conventional fast counters.

* This work was supported by the ONR.

MONDAY EVENING AT 8:00

Sexson Auditorium, Pasadena City College

(R. F. BACHER presiding)

IA1. The Expanding Universe. FRED HOYLE, *Cambridge, England.*

TUESDAY MORNING AT 9:00

Room 201, Bridge

(C. C. LAURITSEN presiding)

Invited Papers

J1. The Stanford Linear Electron Accelerator. R. L. KYHL, *Stanford University.* (45 min.)

J2. The California Institute of Technology Synchrotron. R. V. LANGMUIR, *California Institute of Technology.* (30 min.)

J3. Recent Experimental Evidence Concerning Vo Particles. ROBERT B. LEIGHTON, *California Institute of Technology.* (30 min.)

J4. Some Theoretical Problems Presented by the V Particles. RICHARD C. FEYNMANN, *California Institute of Technology* (15 min.)

J5. Electron-Induced Showers. ROBERT HOFSTADTER AND ASHER KANTZ. *Stanford University.* (30 min.)

TUESDAY AFTERNOON AT 1:30

Room 201, Bridge

(R. F. CHRISTY presiding)

Contributed Papers

K1. Spectrum of Particles from Lead Bombarded by 32-Mev Protons. ROBERT M. EISBERG AND GEORGE J. IGO, *Radiation Laboratory, University of California, Berkeley.*—The inelastic and elastic particles scattered from lead when bombarded with 32-Mev protons were observed at 90° to the incident beam. Particles were detected in a telescope consisting of a proportional counter in coincidence with a sodium iodide scintillation counter. The energy of the particles was determined by pulse-height analysis on the scintillation counter pulses. The coincident proportional counter measurement of ionization insured that the particles counted in the scintillation counter were heavy and charged. The observed energy spectrum does not appear to agree with that predicted by the Weiskopf "boil off" theory in that there are too many high energy particles.

K2. The Scattering and Absorption of π^+ Mesons by Aluminum. J. F. TRACY. *Radiation Laboratory, University of California, Berkeley.*—A beam of π^+ mesons has been passed through five ½-inch aluminum plates in an argon-filled cloud chamber in a field of 5200 gauss; 3976 tracks making 15,359 plate traversals at energies between 25 and 100 Mev (mean energy 49 Mev and average path per traversal 1.57 g/cm²) have been observed. μ^+ contamination was approximately 13 percent. Positron contamination was negligible. Twenty stops; 34 scatters $\geqslant 30°$; and 34 1-prong, 21 2-prong, one 3-prong, and one 4-prong stars were observed. All stops were reasonably accounted for by scatterers and stars hidden by the geometry. Only the faster prongs escape the aluminum without difficulty. If one assumes them to be protons, 49 prongs had more than, and 34 had less than ~30 Mev. The fast prongs were isotropic; the slow prongs, predominantly forward. One unusual event consisting of a 1-prong star and a 70-Mev electron-positron pair in coincidence may be interpreted as an inelastic charge-exchange scatter. The scattering is roughly isotropic except for a dip at 60°–90°. Cross sections (taken over all energies and corrected for geometry and beam contamination) are σ (scat), 162±28 mg; σ (star), 234±31 mb; and σ (total), 396±41 mb. All cross sections rise rapidly with energy.

K3. π^- Mesons Produced in a Cloud Chamber by High Energy Neutrons. FRANKLIN C. FORD AND WILSON M. POWELL, *Radiation Laboratory, University of California, Berkeley.*—The production of π^- mesons in oxygen by neutrons with energies around 310 Mev has been observed in the gas of a Wilson cloud-chamber filled with oxygen and water vapor. The energy and angular distribution for over one-hundred events has been obtained. The neutrons were produced by bombarding a LiD target with 340-Mev protons.

K4. The Radiofrequency Fine Structure of the Photon Beam from the Berkeley Synchrotron. RICHARD MADEY, KENNETH C. BANDTEL, AND WILSON J. FRANK, *Radiation Laboratory, University of California, Berkeley.*—The full energy spread out bremsstrahlung beam of the Berkeley synchrotron was shown to be emitted in sharp burst with the 47.7 megacycle frequency of the electrons in the doughnut. A two-counter telescope, located at about 20 inches away from a ¼-inch lead target and about 20 degrees from the photon beam direction, was used to measure an accidental coincidence counting rate as a function of the length of delay line in one input to the coincidence circuit. An estimate of the width of a single pulse of photons can be obtained from the measurement by unfolding the Gaussian resolution function of the coincidence circuit. If the time variation of the intensity of the photon beam is assumed to be a Gaussian function, then the rms value of that Gaussian is found to be less than 1.5×10^{-9} second. A calculation by E. M. McMillan[1] indicates that the full energy photon beam should exhibit fine structure if the amplitude of the azimuthal phase oscillations at full energy is less than about one radian. The experimental result is another confirmation of the theory of phase stability.

[1] E. M. McMillan (private communication).

K5. β-Decay of Cu^{67}. HARRY T. EASTERDAY, *Radiation Laboratory, University of California, Berkeley.*—The 60-hour β-activity of Cu^{67} produced by (α, p) on Ni and $(d, 2p)$ on Zn has been investigated with a thick lens spectrometer and coincidence counters. The β-spectrum is found to contain three continuous groups with maximum energies of 577, 484, and 395 kev and coversion electrons from 92- and 182-kev transitions. These results along with the fact that $\gamma-\gamma$ coincidences are absent indicate that the β-transitions are to the ground and first two excited states of Zn^{67}. Measurements of the conversion coefficients of the Ga^{67} γ-rays have also been made. Using these data and the previous results on the K capture of Ga^{67},[1,2] spin assignments for the Zn^{67} levels are suggested.

[1] A. Mukerji and P. Preiswerk, Helv. Phys. Acta **25**, 387 (1952).
[2] A. R. Brosi, Oak Ridge National Laboratory (private communication).

K6. Further Evidence for the Process $p+d\rightarrow t+\pi^+$. WILSON J. FRANK, KENNETH C. BANDTEL, RICHARD MADEY, AND BURTON J. MOYER, *Radiation Laboratory, University of California, Berkeley.*—A two-counter telescope was placed at a triton angle of 8° and another at the correlated pion angle of 110°. The four *trans*-stilbene counters were connected to a quadruple coincidence circuit having a resolution time of three millimicroseconds. The tritons are confined within a twelve-degree cone, which allows the triton telescope to be ten feet farther from the target than the pion telescope without loss of solid angle. This geometry permits the measurement of the triton velocity and the suppression of the scattered proton background by counting between the radio-frequency proton pulses from the cyclotron. The evidence for the process is as follows: (1) The CD_2-C difference obtained at the correlated angles disappeared if the telescopes and the beam axis are noncoplanar, or if one telescope is moved from its correlated angle. (2) The particles observed at the triton (or pion) telescope have the energy expected of the triton (or pion) to within ten percent. (3) The particles observed at the triton telescope have the velocity expected of the triton to within fifteen percent. The uncorrected differential cross section is 0.24±0.02 microbarn/steradian at a center-of-mass pion angle of 130° and at a laboratory proton energy of 340 Mev.

K7. A Test of the Charge Symmetry Hypothesis. H. W. WILSON AND WALTER H. BARKAS, *Radiation Laboratory, University of California, Berkeley.*—When alpha-particles bombard carbon, for every process leading to the emission of a positive meson there exists a mirror process leading to the emission of a negative meson. If the charge symmetry hypoth-

esis is valid, one would therefore predict a plus/minus ratio of unity for pion production under the conditions where the Coulomb barrier can be neglected. An experimental arrangement was employed to measure this ratio which eliminates to a large extent the known sources of systematic error. For mesons of nominal energy 15 Mev (total spread 11–21 Mev), the plus/minus ratio from carbon for mesons emitted at 90° to the 375-Mev alpha-particle beam was found to be 0.72 with a standard deviation of 0.17. Estimation of the expected depression of the ratio caused by Coulomb effects has been made.[1] It is concluded that the measured ratio agrees within its standard deviation with that anticipated on the basis of the charge symmetry hypothesis. Another experiment which attempted to utilize mesons of ≈30 Mev failed because the obtainable meson flux was too low. With the same apparatus the plus/minus ratio for pions emitted at 90° to a 330-Mev proton beam bombarding carbon was measured. A ratio of 5.4 ± 0.8 was found.

[1] B. Fried and S. Gasiorowicz (private communication).

K8. Total Cross Sections for Positive Pions. D. STORK, *Radiation Laboratory, University of California, Berkeley.*—The total cross section for positive pions is being studied for several light nuclei as a function of energy in the neighborhood of 50 Mev. Pion beams of various energies are made by bombarding a polyethylene or carbon production target with the 340-Mev external proton beam of the Berkeley synchrocyclotron. The energy is selected by means of a 90° magnetic deflection. A coincidence from two stilbene scintillation counters placed in front of the sample triggers an oscilloscope sweep. Pulses from the front two counters and from a 14-inch diameter liquid scintillation counter placed behind the sample appear on the oscilloscope trace separated in time by means of delay lines. The traces are photographed on continuously moving film. An attenuation event is one in which the pulse from the back counter is absent. The attenuated pions are distinguished from electrons, stopped muons, and random background by means of a pulse-height analysis of the pulses from the front two counters as determined by examining the film. The cross section at 50 Mev for beryllium, carbon, and aluminum is about two-thirds the nuclear area.

K9. A Study of the Pick-Up Process in Proton-Deuteron Scattering. A. BRATENAHL AND B. J. MOYER, *Radiation Laboratory, University of California, Berkeley.*—To account for the unexpectedly large yield of high energy deuterons produced at small angles by high energy proton bombardment of nuclei, a mode of production has been proposed in which a nucleon is transferred from a target nucleus to the incident nucleon, the resulting pair emerging as a deuteron. This transfer or rearrangement process has been termed pick-up. According to the theory of this process, investigation of the yield of pick-up deuterons can furnish information on the wave function of nucleons in a nucleus. A reasonably direct test of the pick-up hypothesis consists in a characteristic connection between the angular distribution and the energy dependence of the yield. In the present experiment, the test is applied in the case where deuterium is the target nucleus. Observations are made of the elastic deuteron recoils in the angular range extending from 0° to 20°; the region theory shows should be dominated by pick-up. Absolute yields are obtained at these angles for incident proton energies of 95, 112, and 138 Mev. The result shows that the theory is supported by the experiment in regard to the features of the test except that the absolute yield is only 55 percent of that predicted.

K10. On the Ratio of π^+ to π^- Mesons Produced by Gamma-Rays. JAMES EDWARD CAROTHERS, *Radiation Laboratory, University of California, Berkeley.*—The minus to plus production ratio for pi-mesons produced in the 320-Mev photon beam of the Berkeley synchrotron has been measured at 60°, 90°, and 150° to the beam for beryllium and at 90° for carbon. Identification of the mesons was made by using a magnet to select a desired momentum interval and measuring the velocity of the particles delivered by the magnet. The results were as follows:

	Be	C
60°	1.93 ± 0.12	
90°	1.96 ± 0.10	1.27 ± 0.06
150°	1.92 ± 0.11	

The relative production of positive and negative mesons at 90°, per proton for positives and per neutron for negatives, from beryllium and carbon was π^+ Be/π^+ C $=1.24\pm0.09$; π^- Be/π^- C $=1.44\pm0.08$. The limits shown are in terms of standard deviation.

K11. Phase-Reversal Focusing in Linear Accelerators. MYRON L. GOOD, *Radiation Laboratory, University of California, Berkeley.*—A modification, applicable to the linear accelerator, of the focusing principle discovered by Courant, Snyder, and Livingston[1] is presented. No foils, grids, magnets, or electrodes are used. One introduces, at periodic intervals along the machine, repeat lengths which are alternately greater than and less than the synchronous repeat length $l=\beta\lambda$. This causes the synchronous particle to alternately lead and lag the rf peak by the synchronous phase angle $|\phi_s|$. (This does not affect the energy gain.) It has been pointed out by McMillan[2] that in a linear accelerator without grids or foils in the path of the beam, one cannot have first-order radial focusing and phase stability at the same time. The above modification causes the beam to periodically alternate from a condition of radial defocusing (with phase stability) and one of radial focusing (with phase instability). Both the radial and phase equations of motion become, for small oscillations, the Hill-Meissner equation, and over-all stability results. The strength of focusing is comparable to that obtained by using grids. The phase acceptance angle is being investigated.

[1] Courant, Livingston, and Snyder, Phys. Rev. (to be published).
[2] E. M. McMillan, Phys. Rev. **80**, 493 (1950).

K12. Variation of Moisture Content in Nuclear Track Emulsion. ALBERT J. OLIVER, *Radiation Laboratory, University of California, Berkeley.*—Ilford emulsions for nuclear research, both unprocessed and processed, have been brought to equilibrium with different relative humidities and then measured in thickness, volume, and weight. The variation of emulsion volume and weight with time in a vacuum, for different thicknesses of unprocessed emulsion on glass, has been followed. Moisture diffusion rates through the emulsion and the nonlinear relationship between thickness and water content have been investigated. Thicknesses were measured by a dial indicating micrometer. Volumes were measured by displacement. Humidities were maintained in some cases by salt solutions and in others by aqueous solutions of glycerine. New values have been computed for emulsion density and for the dependence of the shrinkage factor on relative humidity and processing procedure.

K13. Pion Production at 180° by Protons on Carbon. STANLEY L. LEONARD, *Radiation Laboratory, University of California, Berkeley.*—The pion production cross section at 180° to the beam for carbon bombarded by 340-Mev protons has been measured, using photographic emulsion techniques. Ilford C-2 emulsions imbedded in Cu or Al absorbers were exposed to magnetically separated beams of positive and negative pions emerging from graphite targets at a series of energy intervals. Mesons were identified and counted by the usual microscope techniques. The values, for $\theta=180°$, of $d\sigma/d\Omega dE_\pi$ as a function of energy and of the integrated cross section $d\sigma/d\Omega$ have been obtained for both positive and negative

pions and the plus-minus ratios have been calculated. Corrections are made for errors resulting from pion decay in flight, the finite thickness of the target nuclear absorption in the Cu and Al, and for background pions which are probably produced in the magnet pole pieces by the fringe of the proton beam.

K14. Nuclear Scattering of "300" Mev Neutrons. W. P. BALL, BURTON J. MOYER, AND ROBERT E. RICHARDSON,* *Radiation Laboratory, University of California, Berkeley.*—Elastic and inelastic cross sections for "300" Mev neutrons on nuclei were determined. Ring type scatterers, polyethylene n, p converters with scintillation counters, and triple coincidence units were used. Ratios of counts in the scattered beam to those in the direct beam yielded absolute values for the cross sections. Angular distributions of neutron nuclear differential elastic scattering cross sections were obtained for carbon, aluminum, copper, and lead. The distribution for lead seems to approximate a diffraction pattern. The fit to a diffraction pattern gets progressively worse as one goes to lighter elements. Differential elastic cross sections were integrated graphically over the angles measured. The resulting integrals added to corresponding inelastic results yield total cross sections which are in agreement with those obtained by DeJuren and Moyer. Elastic and inelastic cross sections obtained in this experiment compared with lower energy results of others, show the elastic part is primarily responsible for the rapid drop in total cross sections with energy above 100 Mev found by DeJuren and Moyer.

* Now at Project Lincoln, M. I. T.

K15. Secondary Particles Induced by 375-Mev Alpha-Particles. R. W. DEUTSCH AND W. H. BARKAS, *Radiation Laboratory, University of California, Berkeley.*—Thin targets of Be, Al, Ni, Ag, Au, and U have been bombarded by an internal cyclotron beam of 375-Mev alpha-particles. Secondary particles emerging from the disintegration of the nuclei are detected in Ilford C2 nuclear track plates located beneath the median plane of the cyclotron. There are three specific positions for the nuclear plates corresponding to mean proton energies of about 5, 10, and 20 Mev. A secondary particle is identified by measurement of its radius of curvature, range, and specific ionization. The light secondaries including H^1, H^2, H^3, He^3, and He^4 fall on identifiable loci. Heavier fragments are also identified by taking into account electron pick-up.[1] Relative abundances of the secondary particles and momentum spectra are obtained.

[1] W. H. Barkas, University of California Radiation Laboratory Report No. 1937.

K16. π^+/π^- Ratios Measured with the Use of the Spiral Orbit Spectrometer.* RYOKICHI SAGANE, *Radiation Laboratory, University of California, Berkeley.*—The results of the experiment, preliminarily reported earlier,[1] are as follows: The π^+/π^- ratios for mesons produced by 345-Mev protons at 90° for energies 13±4 Mev, 18±4 Mev, and 41±2 Mev have been obtained. The ratios are Be (1.3±0.4, 5.2±1.3, 5.8±1); C (−, 5.0±1, 11.5±2.5); and Al (4±0.8, 2.5±1.2, 1.6±0.4), respectively. Plates for Cu, Ag, and Pb are now being scanned. Several developmental tests for the use of the spiral orbit spectrometer have been made. The following items will be discussed: (1) The vertical focusing is working favorably, and it is possible to adjust this effect. (2) The energy resolution of the spectrometer was usually too high compared with the energy spread caused by absorption through the targets. It is possible to reduce the resolution by adding annular ring pole pieces and increase the intensity. (3) To reduce energy spread due to absorption both for mesons and protons, thin-walled conical or tubular targets were used. (4) The projected range straggling curve of 8-Mev mesons in C2 emulsion was obtained. This enables one to calculate the absolute number of mesons arrived at the detector.

* G. Miyamoto, Proc. Phys. Math. Soc. Japan **24**, 676 (1942); **17**, 587 (1943); M. Sakai, J. Phys. Soc. Japan **5**, 178 (1950).
[1] R. Sagane and P. C. Giles, Phys. Rev. **81**, 653 (1951).

TUESDAY AFTERNOON AT 1:30

Room 155, Arms

(PAUL KIRKPATRICK presiding)

Contributed Papers

L1. Nuclear Resonance Line Broadening and Quadrupole Splitting in Metallic Beryllium.* W. D. KNIGHT, *University of California, Berkeley.*—The nuclear magnetic resonance absorption line in powdered beryllium metal is a well-resolved triplet. The observed width of the central component is 3.5 kc, and the splitting of either satellite is 12 kc. The line width increases slightly with field and temperature. The temperature dependence of the line width roughly confirms relaxation time measurements in pointing to deviations from the usually assumed inverse temperature dependence of the spin-lattice relaxation time. Beryllium is hexagonal, and its behavior will differ from that of cubic metals such as copper or sodium, in which the position of the resonance is simply shifted due to local fields generated primarily by the conduction electrons in s states. It is proposed that the excessive line width (about six times the calculated nuclear dipolar width) and the triplet structure arise from two mechanisms related to the noncubic crystal structure. First, the conduction electron local field will be anisotropic: in a polycrystalline material the s states will shift the line, while other contributions will produce broadening. Second, quadrupole coupling will spread the absorption spectrum into three peaks, corresponding to $I=3/2$. We may combine the observed splitting with Kittel's (unpublished) calculation of the contribution of the ion cores to the electric field gradient to estimate the nuclear electric quadrupole moment of Be^9 to be of the order of 0.02×10^{-24} cm².

* Supported in part by the ONR.

L2. Photoproduction of Meson Pairs.* R. D. LAWSON AND S. D. DRELL,† *Stanford University.*—For pseudoscalar mesons interacting with nucleons via pseudoscalar coupling, it follows from a perturbation calculation that the cross section for photoproduction of (π^+, π^-) pairs near threshold dominates over other possible meson pair creation cross sections by a factor of the order of $(M/\mu)^2$. This is best seen by transforming the pseudoscalar interaction Hamiltonian with the Dyson transformation.[1] The transformed Hamiltonian can be separated into one large pair term $2M(g^2/\mu^2)\int\bar{\psi}\psi\varphi^2\,d\tau$ plus other smaller terms, one of which is the usual pseudovector coupling form. This large term gives the dominant contribution to the (π^+, π^-) pair production process, but cannot contribute to the pair process in which one of the mesons is a π^0 and the other

is charged, since it cannot change the charge state of the nucleon. The (π^0, π^0) cross section is small in virtue of the fact that the γ-ray interacts only with the nucleon in this process. The total (π^+, π^-) cross section for 400-Mev incident γ-rays in the laboratory system is approximately $(g^2/4\pi)^2$ millibarns. This value is considerably larger than that given by Brueckner and Watson[2] who assume pseudovector coupling. Measurement of π^- mesons produced by γ-rays on protons may yield valuable information on the operation of the above pair term in the pseudoscalar coupling.

* Assisted by joint program of the ONR and AEC.
† Now at the Department of Physics, M. I. T.
[1] F. J. Dyson, Phys. Rev. **73**, 929 (1948).
[2] K. Brueckner and K. Watson, Phys. Rev. **87**, 621 (1952).

L3. Remark on the Second-Order Electron Self-Energy. H. P. STAPP, *University of California, Berkeley.*—The matrix formulation of perturbation theory is based on a set of unitary transformations which are designed to carry a (Hamiltonian) matrix progressively closer to diagonal form. The transformation corresponding to the second-order correction will approximately diagonalize any finite matrix provided only that the coupling parameter is sufficiently small. It is shown, however, that when this transformation is applied to the infinite matrix of the self-energy problem, the affected off-diagonal elements become infinite regardless of how small the perturbation parameter is made. Since the matrix is carried further from diagonal form by an infinite amount, even as the coupling parameter approaches zero, the (second-order) perturbation energy should not be considered a valid correction, and a different method of approximation is indicated. A modification of the usual second-order transformation can be found which exactly diagonalizes that portion of the Hamiltonian which contributes in second order. Using positron theory, this gives a finite mass correction of about one percent whose chief form is of the form $\alpha \log(1/\alpha)$, where α is the fine structure constant. No cutoff is used. The form of the solution is non-analytic at the origin, in accordance with a recent remark by Dyson.

L4. Electro-Disintegration of Nuclei. KARL L. BROWN AND RICHARD WILSON,* *Stanford University.*—High energy electrons (24–34 Mev) from the Stanford 35-Mev linear accelerator were used to study the ratio $\bar{F}$ of the activity $A^s(\gamma, n) \times (A-1)^s$, due to the bremsstrahlung of the electrons to the activity $A^s(e, e'n)(A-1)^s$, produced by the electromagnetic field of the electrons for the isotopes Cu^{63}, Zn^{64}, Ag^{109}, and Ta^{181}. Results are compared with the theoretical calculations of Blair.[1] The Weizacker-Williams virtual photon method gives a value of $8\pi/3$ for $\bar{F}$. The experiment was the "stacked foil" type—the electron beam passed successively through a thin foil of the element being studied, a copper radiator, and a second thin foil. The resulting foil radioactivity was measured with Geiger counters. Preliminary results indicate (within experimental error) that the ratio $\bar{F}$ varies linearly with energy. $\bar{F}$ at 34 Mev is 8.5 ± 0.5, 8.7 ± 0.5, 7.5 ± 0.3, 6.2 ± 0.7; and at 33.5 Mev is 6.9 ± 0.4, 7.4 ± 0.5, 6.2 ± 0.3, 5.2 ± 0.6 for Cu, Zn, Ag, and Ta, respectively.

* Present address: Clarendon Laboratory, Oxford, England.
[1] J. S. Blair, private communication and Phys. Rev. **75**, 907 (1949).

L5. Decay Scheme of Ga^{67}. W. E. MEYERHOF, L. G. MANN, AND H. I. WEST, JR., *Stanford University.*—Using NaI(Tl) scintillation counters in coincidence (with differential discrimination) the decay scheme of Ga^{67} has been investigated. This isotope decays by K capture to excited levels of Zn^{67}. Positrons occur to less than 0.01 percent. Gamma-rays are found as follows: 0.090 Mev (4 percent), 0.092 (73.5 percent $\gamma+e^-$; $e^-/\gamma\sim0.6$), 0.182 (21.5 percent), 0.20 (2 percent), 0.30 (12.5 percent), 0.39 (4.5 percent), 0.5 (<1 percent), 0.9 (~1 percent), 1.1 (<1 percent, ?). (The percentages refer to a Ga^{67} decay probability of 100 percent.) The 0.092 gamma-ray is delayed by 8 ± 1 μs (half-life) with respect to the 0.090, 0.20, and 0.30 gamma-rays. The gamma-rays may be ordered into the following level scheme of Zn^{67} (percent K capture to each level and spin assignment given in brackets): 0 Mev (~0 percent; $f_{5/2}$), 0.092 (57 percent; $\frac{1}{2}^-$), 0.182 (23.5 percent; $\frac{3}{2}^-$), 0.39 (19 percent; $\frac{3}{2}^-$), 0.9 (~1 percent), 1.1 (<1 percent ?). The spin assignments are consistent with a preliminary analysis of gamma-gamma angular correlation experiments. The authors are very much obliged to the University of California, Berkeley, for producing the Ga^{67} in the 60-inch cyclotron by the Zn (p, n) reaction.

L6. Radiative Correction to the Collision Loss of Heavy Particles. V. Z. JANKUS, *Stanford University* (introduced by L. I. Schiff).—The usual expression for the collision loss of a heavy particle considers only the elastic collisions with atomic electrons. Recently, Jauch[1] has calculated the radiative correction due to the emission and re-absorption of virtual photons and emission of very soft, real photons. In our calculation the contribution due to the emission of hard photons is also included. The calculation, like that of Jauch, is performed in a Lorentz frame, in which the heavy particle is initially at rest. To simplify the calculation, it is assumed that the bombarding electrons in this Lorentz frame are extremely relativistic, and the Bethe-Heitler formula is used. The results show that the collision loss is increased by an amount that gets bigger as the energy increases; it is 1 percent when the incident particle energy is 100 times its rest energy. In contrast, Jauch found a decrease of 3 percent for the same energy. Since the Bethe-Heitler formula does not take into account the recoil of the scattering center, our results may be in error when the recoil velocity of the heavy particle in the center-of-mass frame is comparable with c.

[1] J. M. Jauch, Phys. Rev. **85**, 950 (1952).

L7. On the Mean Lifetime of V^0 Particles.* R. B. LEIGHTON AND W. L. ALFORD, *California Institute of Technology.*—The mean rest-lifetime of V^0 particles has been estimated, using measurements on 134 cases of V^0 decay. A case was rejected (1) if its decay point lay outside certain fiducial surfaces placed well inside the visible volume of the cloud chamber, (2) if the included angle between its two decay tracks was $\leqslant 10°$, or (3) if the V^0 path was seriously obstructed from view either above or below the decay point. The time t_i at which the ith V^0 particle decayed after crossing the upper fiducial boundary, and the time T_i that it would have remained within the fiducial volume had it not decayed, both measured in the rest system of the V^0 particle, were calculated for the remaining $N=74$ cases. The maximum-likelihood value τ of the mean life was then calculated by iteration, using the formula $\tau=\Sigma[t_i+T_i/(-1+\exp T_i/\tau)]/N$. This gave $\tau=2.5\pm0.7\times10^{-10}$ sec, where the indicated error includes both the effect of the limited sample and the effect of the finite value of the T_i. The mean value of t_i/T_i was 0.30. The mean life of 48 cases, whose apparent energy release upon decay was $\leqslant 50$ Mev was $\tau_L=3.0\pm0.8\times10^{-10}$ sec, and that of 26 cases, whose apparent energy release was >50 Mev, was $\tau_H=1.6\pm0.5\times10^{-10}$ sec. There is thus no clearly significant difference between these two groups.

* Assisted by the joint program of the ONR and AEC.

L8. Cerenkov Radiation in a Dispersive Medium. H. MOTZ AND L. I. SCHIFF, *Stanford University.*—In a recently published book on optics, Sommerfeld[1] states that the direction of propagation of Cerenkov radiation in a dispersive medium is given by the usual formula,[2] if the velocity of light in the medium is taken to be the group velocity. This is contrary to the generally accepted result, according to which the phase velocity must be used. The latter is shown to be correct,

and the role of the group velocity is discussed in a way similar to that given by Tamm.[3] In particular, a wave-packet argument is used to show that the cone of constant radiation amplitude with vertex at the electron has an angular opening that depends on the dispersion, so that the radiation does not, in general, propagate perpendicular to the planes tangent to this cone. A full account will be published in the American Journal of Physics.

[1] A. Sommerfeld, *Vorlesunger Über Theoretische Physik, Band IV, Optik* (Dieterich Verlag, Wiesbaden, 1950), p. 341.
[2] See, for example reference 3, or L. I. Schiff, *Quantum Mechanics* (McGraw-Hill Book Company, Inc., New York, 1949), p. 264.
[3] I. Tamm, J. Phys. U.S.S.R. 1, 439 (1939); see especially Sec. 5.

L9. Agreement of Theoretical and Experimental Intensities of Soft Continuous X-Rays. R. W. HENDRICK, JR., *Stanford University.*—Calculations of the intensity of thick-target continuous x-radiation from 8 to 15A permit comparison with experimental values.[1] The theoretical intensities are obtained by integrating the emitting power of the electrons as they are stopped in the target. Emitting powers are extrapolated from calculations[2] using Sommerfeld's theory of radiation. Negligible x-ray absorption in the target results from the short range of the emitting electrons. The intensity of 10A radiation from a tungsten target can be approximated with less than 3 percent error in the region 1.25 to 3.5 kilovolts by the expression $I=C[3(V-V_0)-(V-V_0)^2+0.17(V-V_0)^3]$, if V is expressed in kilovolts. V_0 is 1.24 kilovolts, the minimum voltage for producing 10A x-radiation, and C is a determinable experimental constant. Experimental intensities measured by Stephenson and Mason (1.25 to 2 kv) deviate from the theoretical values by less than 4 percent of the 2 kv intensity if they are normalized to agree at 1.8 kv.

[1] S. T. Stephenson, and F. D. Mason, Phys. Rev. **75**, 1711 (1949).
[2] P. Kirkpatrick and L. Weidmann, Phys. Rev. **67**, 321 (1945).

L10. The Scanning X-Ray Microscope. HOWARD H. PATTEE, JR., *Stanford University.*—A proposed new type of microscope especially suitable for x-rays uses no optical elements between the specimen and image, the magnification being done electronically. The x-ray source is produced by focusing field-emission electrons onto a foil target, to the outside of which the specimen is closely affixed. This electron probe is scanned over the specimen area in synchronism with a scan on a display kinescope. The intensity of the kinescope is modulated by the output of a photomultiplier which detects the x-rays passing through the specimen. The magnification is the ratio of the kinescope sweep-length to the sweep-length of the x-ray source. Since the specimen is in direct contact with the source the diffraction effects are negligible, and the resolution does not in principle depend on the wavelength of the radiation used, but on the effective size of the source. Such a technique might therefore be used with light in order to overcome the resolution limit set by diffraction. Construction of the microscope is now in progress.

L11. Refinement and Resolution in Reconstructed Wavefront Microscopy. HUSSEIN M. A. EL-SUM AND PAUL KIRKPATRICK, *Stanford University.*—Removal of photographic noise is a double problem. Noise in the hologram is effectively smoothed out by axial rotation of all lenses and filters in the system. Noise occurs in the reconstruction, even from a clean hologram, because of actual dirt, physical defects (astigmatism, optical inhomogeneity, surface irregularities) in the optical components, and the presence of the out-of-focus conjugate image. Methods have been developed for the suppression of most of these nuisances. Disturbance arising from the conjugate image may be obviated by leaving the object to be imaged in the system along with its hologram during the reconstruction exposure. The object gives rise to a diffraction pattern which is complementary to the undesired conjugate image, and hence, they combine into a uniform photographic field. Alternatively, it is proposed to make two holograms with their background radiations differing in phase by 90°, and to reconstruct from both simultaneously, using a beam splitting and reuniting optical system. Such a process would cancel the unwanted image by interference. The resolution of a reconstructed wave-front micrograph made with a given lens may surpass that of any image directly formed by the same lens.

L12. Field Emission: Large Current Densities, Space Charge, and the Vacuum Arc. W. P. DYKE AND J. K. TROLAN, *Physics Department, Linfield College, McMinnville, Oregon.*—Field emission was obtained from a single crystal tungsten emitter under conditions of very high vacuum and clean surfaces. The geometry of the emitter was determined by electron microscopy permitting accurate calculation of both the surface electric field and an average current density. The use of pulse electronic techniques extended the observations to the upper limit of the current densities for which the normal field emission was stable. Above this limit an explosive vacuum arc occurred between electrodes. From these experiments the following conclusions were drawn: (1) The wave-mechanical, image-force, corrected theory quantitatively predicted the observed average current density up to that density for which space charge dominates the emission. (2) Space charge was effective at a current density of the order of 10^7 amperes/cm^2 where a marked deviation occurred from the usual current-voltage relationship. Space charge effects permitted the simultaneous operation of multiple emitting areas of differing geometries. (3) At a still higher critical current density in the range 10^7 to 10^8 amperes/cm^2, a field emission initiated vacuum arc occurred between electrodes resulting in a change of emitter geometry. Current density was the dominant criterion for the initiation of the vacuum arc.

L13. Electron Bunching in a Disk-Loaded Circular Wave Guide. R. B. NEAL, *Microwave Laboratory, Stanford University.*—This device has been developed to supply axially bunched electrons to the Stanford Mark III Linear Accelerator. Good initial bunching is necessary to obtain a sharp electron energy spectrum at the accelerator output. The buncher consists of a disk-loaded circular wave-guide structure 32 inches long operating in the $\pi/2$ mode. The hole diameters in the disks and the i.d. of the circular wave-guide are tapered so that the phase velocity increases from $\beta=0.5$ at the beginning to $\beta=1.0$ at the end, while the axial field strength increases by a factor of 10. Electrons are injected from an electron gun at 80 kv ($\beta_e=0.5$). About 95 percent of the electrons are bound to the traveling wave and emerge from the buncher with energies of 4 Mev. An output current of 10^{12} electrons/pulse has been obtained bunched within 20 degrees on the wave front. With this degree of bunching, all electrons at the output of the accelerator should have energies within 98 percent of maximum. The power source for the buncher is a 10.5 cm, 10 megawatt, klystron amplifier delivering 1.4 microsecond pulses at 60 cps about 2/3 of the power passes through the buncher and is used in the accelerator proper.

TUESDAY AFTERNOON AT 1:30

Room 119, Kerchoff

(R. B. BRODE presiding)

Contributed Papers

M1. Multiple-Beam Fringes of Equal Chromatic Order. W. F. KOEHLER, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—When the thickness or change in thickness of an air film between silvered flats is measured by means of fringes of equal chromatic order, a systematic error is introduced due to a deviation from the phase change upon reflection from that assumed by the Airy intensity distribution and due to the neglect of the thickness of the partial silver coating. A method of reducing this error will be discussed.

M2. Diffraction by an Ionized Trail. CHARLES H. PAPAS, *California Institute of Technology, Pasadena.*—In a previous paper[1] the diffraction of a plane electromagnetic wave by a perfectly conducting cylinder was examined by use of the Levine-Schwinger variational principle.[2] The incident wave was assumed to be linearly polarized parallel to the axis of the cylinder. Using the same technique Takahashi, Watanabe, and Tanimoto[3] treated the complementary case of perpendicular polarization. In this paper essentially the same method of attack is used to calculate the parallel and perpendicular scattering cross sections of an ionized column produced by a traveling meteor.[4] Mathematical difficulties, which limit the applicability of existing theories[5] to small values of a/λ (a = effective diameter of ionized trail), are removed by use of the variational principle.

[1] C. H. Papas, J. Appl. Phys. **21**, 318 (1950).
[2] Comm. Pure and Appl. Math. **3**, 355 (1950).
[3] Paper read at Annual Meeting of the Physical Society of Japan, November 2, 1950.
[4] N. Herlofson, Phys. Soc. Rep. Prog. Phys. **11**, 444 (1948).
[5] N. Herlofson, Arkiv Fysik **3**, 247 (1951).

M3. Law of Equilibrium Between Coexisting Phases. GEORGE ANTONOFF, *Fordham University.*—My law as applied to two liquid layers is $\gamma_{12}=\gamma_1-\gamma_2$ (1), where γ_{12} is the interfacial tension, γ_1 and γ_2 surface tensions of both layers. Its theory indicates that it is a law of equilibrium and thus can have no exceptions. However, the systems often remain in false equilibrium, especially if cp and if they contain the groups OH and COOH. Thus, no measurements have significance, unless extended over a long enough period. In systems like CS_2 and H_2O equilibrium is never reached, owing to irreversible reaction; they are outside my law. Criterions of equilibrium are (1) conformity with the law (1), (2) two layers in equilibrium have the same vapor pressure, (3) the same boiling point, and (4) the same freezing point. Recently Donohue and Bartell[1] contested the above, but did not describe any experiments of long duration. Also, Rose and Seyer[2] described results equally meaningless and for the same reason. Carl Benedicks[3] attributes his results to nonvalidity of law (1) for systems with OH and COOH groups. In an earlier reference,[4] I explained why the effect cannot be the result of adsorption.

[1] Donohue and Bartell, J. Phys. Chem. **55**, 480 (1952).
[2] Rose and Seyer, J. Phys. Chem. **55**, 439 (1951).
[3] Carl Benedicks, Arkiv Fysik **3** 416 (1951).
[4] George Antonoff, J. Phys. Chem. **46**, 497 (1942).

M4. Propellant Burning Rate Calculations. G. B. SHOOK, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—In an extension of previous work on steady-state burning rates for solid rocket fuels,[1] a system of calculations has been devised which predicts the dependency of the rate on pressure, storage temperature, and local gas velocity. Principal parameters involved are (a) heat of explosion, (b) density, (c) specific heat, and (d) reaction rate constants for solid phase reaction. The essential variables are (a) temperature gradient at burning surface, (b) reaction rate integral, and (c) surface temperature. These are obtained by the use of an analog computer (REAC). The calculations are compared with experimental results for several laboratory batch rocket fuels.

[1] R. H. Olds and G. B. Shook, Phys. Rev. **88**, 166 (1952).

M5. The Surface Temperature of a Burning Double-Base Propellant. M. H. HUNT, C. A. HELLER, AND A. S. GORDON, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—The surface temperature of a burning double-base propellant has been measured in the range from one atmosphere to 1000 psi. The measuring technique has been to hold a Pt−Pt 10 percent Rh thermocouple in contact with the burning surface and to record the resulting emf. The temperatures range from 800°C at atmospheric pressure to 1700°C at 1000 psi. From this information and the known variation of burning rate with pressure, an activation energy for the surface reaction may be calculated. The validity of the measurements are discussed, and some corrections to the data are proposed.

M6. Linearized Theory of Spherical Wave Decay. L. M. TANNENWALD, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern* (introduced by F. T. Rogers, Jr.).—A multiple Laplace-transform technique will be given which permits a tractable description of the motion of a spherical wave in a medium (air) having viscosity and heat conductivity (Prandtl number = 0.75).

M7. Geometrical Relations for Solid Propellant Charges for Rocket Motors. E. W. PRICE, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—Dependence of the gas flow field in a solid propellant rocket motor on two geometrical ballistic parameters G and J has been determined in earlier work (e.g., reference 1, where $G=qx/A_p$)[1]. Using the geometrical assumptions of reference 1, and the additional assumption that the charge burning area varies linearly with distance burned in from the initial charge surface, it is shown in the present paper that $G=lb_f f(a, R_i, w)$ and $J=(A_1/A_m)g(a, R_i, w)$, where f and g are algebraic functions. In these relations, w is the fractional distance remaining to be burned into the charge at any time during burning, and a, R_i, l, b_f, and (A_1/A_m) are dimensionless geometrical design parameters descriptive of change in charge surface area during burning, loading density of the motor, length of the charge, perimeter of the charge cross section at the end of burning, and nozzle size, respectively. Combination of these results with those of reference 1 enables one to systematically examine the variation in motor performance as a function of propellant charge geometry and to ascertain the feasible domain of motor performance.

[1] E. W. Price, J. Appl. Phys. **23**, 145 (1952).

M8. Velocity of Sound Apparatus for Liquids at 512 kc. GEORGE G. KRETSCHMAR, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—An ultrasonic interferometer has been constructed for measuring liquid sound velocities

in which all parts in contact with the liquid are made of stainless steel. This has the advantage that measurements may be made on corrosive liquids. The 5-mil stainless steel diaphragm is driven by a quartz crystal at 512 kc with an oscillator and tuned amplifier. The frequency is controlled by continuous monitoring with a Signal Corps Type BC 221 AH frequency meter. This permits measurements of high accuracy to be made. Test measurements were made on water. The average of three measurements was 1498.2 m/sec for the velocity of sound in distilled water at 25°C.

M9. Dependence of Jet-Tone Eigenfrequencies on Aerodynamic and Geometrical Parameters Involved. LLOYD E. SCHILBERG AND A. B. C. ANDERSON, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—An experimental study of the dependence of the spectrum of self-excited eigenfrequencies produced by air-jets, at relatively low Reynolds numbers, has been made. Results, expressed in non-dimensional form, indicate that $[(\Delta p/\rho)^{\frac{1}{2}}]/tf$ is a function of Reynolds number, where Δp is differential pressure across orifice; ρ, density of air; t, thickness of orifice plate; and f, eigenfrequency: In the upper range of Reynolds numbers investigated $[(\Delta p/\rho)^{\frac{1}{2}}]/tf$ is relatively independent of Reynolds number; in the lower range, it rises with decrease of Reynolds number. For any one orifice plate and jet there may be one or more eigenfrequencies rising above the turbulent background noise. Usually one of them is louder than the others. If the value $[(\Delta p/\rho)^{\frac{1}{2}}]/tf = K$ for this one is calculated, the values of $[(\Delta p/\rho)^{\frac{1}{2}}]/tf$ for the others appear to be a multiple or submultiple of K.

M10. Dependence of the Primary Pfeifenton (Pipe Tone) Frequency on Pipe-Orifice Geometry. A. B. C. ANDERSON, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—A derivation is presented of an expression relating the frequency of the *primary Pfeifentöne*, produced in a column of moving gas, to the geometry of the pipe-orifice combination in which the *Pfeifenton* oscillations occur. The *Pfeifentöne* appear to be initiated in and by the gas discharging continuously through the orifice. Comparison is made between results obtained with this expression and experiment. Good agreement is shown between the values of the *primary Pfeifenton* frequencies predicted by the relation and the values obtained by experiment. These results apply for a thin orifice plate and are expressed in nondimensional form. A mechanism for the excitation of these self-excited oscillations is proposed.

M11. A Wave Synthesizing Light Chopper. W. WALLIN, *Michelson Laboratory, U. S. Naval Ordnance Test Station, Inyokern.*—A means is described for modulating a light beam according to any of a class of functions describable by Fourier series.

M12. Detonation in Gases. ARTHUR L. BENNETT, *U. S. Naval Ordnance Test Station, Inyokern.*—Detonation of a stoichiometric mixture of hydrogen and oxygen in a tube 2.5 cm square and a meter long, ignited by a spark, is being studied at initial absolute pressures up to 800 mm Hg. The spectrum λ4000 to λ6500 is predominated by the D lines of sodium, apparently in the normal ratio of intensities. Emission of intermediate strength around λ5500 and λ6200 and a very weak emission of Ca λ4227 are the only other features seen. The intensity variation of the emission is recorded by a photomultiplier and cathode-ray scope. The intensity of the emission measured at a slit 60 cm from the spark rises in a few microseconds to a maximum and decays in about 80 microseconds for an initial pressure of one atmosphere.

M13. Nuclear Magnetic Relaxation in Viscous Liquids. ROBERT L. CONGER, *U. S. Naval Ordnance Test Station, Inyokern.**—Measurements of nuclear relaxation times of water-glycerine solutions of Cu^{++} and Mn^{++} were made over a viscosity range of from 1 to 70 centipoise. Effective magnetic moments of Cu^{++} and Mn^{++} were then calculated from these data and plotted as a function of viscosity. The resulting curve for Mn^{++} decreases gradually in a manner easily explained, while the curve for Cu^{++} shows an anomaly at about 10 centipoise.

* Post Office: China Lake, California.

TUESDAY AFTERNOON AT 1:30

Room 22, Crellin

(W. M. POWELL presiding)

Contributed Papers

N1. The Interference of Waves Generated by the Electric Field. OLEG YADOFF, *Columbia University.*—If we suspend in space, in the presence of atmospheric pressures, two needle electrodes connected with the source of an electrostatic field, we can obtain, by means of the regulation of these electrodes, a situation that creates the phenomenon of the interference of emitted waves. Such an interference can be easily observed on the surface of some not very viscous liquid. If, for instance, two needle electrodes are suspended above the surface of water placed in an open vessel, we can obtain an interference in the form of divergent waves of hyperbolic shape, greatly resembling the interfering waves obtained from the mechanically vibrating needle contacts. In the present case, the electrode is suspended in space above the surface of the liquid, while in the known case of mechanical vibration the needles touch the surface of the liquid. It is preferable to use electrodes charged with the same sign, for example, a negative sign. The enclosed photograph illustrates this phenomenon. The interference occurs not only on the surface but in the liquid itself. The penetrability increases with the increase of the degree of viscosity, but in this case there appears a convection of electrical charges through the liquid. The observed new aspect of the phenomenon of interference may have important applications in industry, for example, in different biological treatments.

N2. Some Electrical Hysteresis Properties of Ice.* FRANK K. TRUBY, *New Mexico Institute of Mining and Technology Socorro, New Mexico.*—Extensive experimentation has shown that the electrical conductivity of ice in the direction of the C axis is by electrons which are provided by impurity centers incorporated during the freezing process. The apparent resistance is dependent upon the sign and magnitude of the applied field. Conductivity measurements made over a continuous cycle of applied potential gradient (−4000 to +4000 volts per cm) exhibit the following characteristics: (a) The ice acts as a body rectifier along the C axis. (b) The front to

back conduction ratio ranges from 0 for low fields to 30,000 for higher values. The minimum electron conductivity is in the direction of the crystal's growth. (c) The conductivity is dependent upon the electrical history giving hysteresis effects with respect to the potential gradient. (d) The character of the hysteresis loop indicates a high degree of coordination in the structure suggestive of a domain regime involving the impurity centers. These results support other evidence that the number of configurations in the resonance pattern of ice is restricted greatly by high coordination within a domain or cellular structure.

* Part of the work here reported was done under contract with the ONR.

N3. The Cellular Nature of Ice Crystals. E. J. WORKMAN, *New Mexico Institute of Mining and Technology, Socorro, New Mexico.*—In an effort to explain some electrical and electromechanical effects observed in the study of ice containing minute quantities of impurities, attempts have been made to find evidence of the role of impurity centers in the crystal regime. Accordingly, a relatively large number of x-ray diffraction patterns and electron photomicrographs of ice have been made. Electron microscope studies reveal that the etched surfaces of all crystals show a fine structure pattern indicative of high binding energy around small hexagonal crystal cells. These small crystals range in size from ½ to 5 microns in width and have a depth ranging from 1 to 10 microns. The size of the unit crystals is independent of growth rate of the sample. Photographs of etched surfaces are shown in evidence that the large single crystals of ice are in fact coordinated mosaics of small hexagonal cells.

N4. A Low Power Water Boiler Type Reactor for Research Use.* M. E. REMLEY AND D. C. WOODS, *North American Aviation, Inc., Downey, California.*—A small homogeneous reactor of the water boiler type[1] has been placed in operation at the Atomic Energy Research Department of North American Aviation, Inc. The reactor core consists of a stainless steel sphere 12 inches in diameter which contains a U^{235} enriched uranyl nitrate solution. The sphere is surrounded by a cylindrical graphite reflector, which in turn is surrounded by a concrete block shield. No cooling facilities are incorporated in the design, and decomposition and fission product gases evolved during operation are collected in a stainless steel accumulator tank. With the present two feet of concrete shielding, the reactor can be operated at a maximum power of one watt and supplies a thermal flux of approximately 4×10^7 neutrons/cm²-sec in a tube through the core. Because of its small cross section, the reactor is ideally suited for cross-sectional measurements by the danger coefficient technique.[2] Data on the operating characteristics, neutron flux distributions, and experimental uses of this low power reactor will be discussed.

* This work was performed under AEC Contract AT-11-1-GEN-8.
[1] Los Alamos Scientific Laboratory, Rev. Sci. Instr. **22**, 489 (1951).
[2] Anderson, Fermi, Wattenburg, Weil, and Zinn, Phys. Rev. **72**, 16 (1947).

N5. Resonance Absorption by Conduction Electrons in Metals. A. F. KIP, T. W. GRISWOLD, AND A. M. PORTIS, *University of California, Berkeley.*—Observation of spin resonance absorption due to conduction electrons in finely divided sodium has been reported.[1] We are continuing this work and have found similar absorption in finely divided lithium. Observations were made in the 9000 mc/sec region. Since the absorption by conduction electrons is independent of temperature, in contrast to the approximate $1/T$ dependence of ordinary paramagnetism, we can rule out the possibility that the observed absorption is due to contamination by small amounts of paramagnetic materials. This is done by making observations at room temperature and at liquid nitrogen temperature with the metallic sample and a small sample of $CuSO_4\cdot5H_2O$ both in the test cavity. The relative sizes of the two signals at the two temperatures confirms the fact that the signal from the metals is essentially temperature independent, in contrast to the copper sulfate. The line width in our sample of lithium is considerably narrower than in sodium. This agrees qualitatively with the idea that metals with longer electron mean free paths give broader absorption lines, as discussed in the following abstract.

[1] Griswold, Kip, and Kittel, Phys. Rev. (to be published).

N6. Electronic Spin Resonance Line Width in Metals. ELIHU ABRAHAMS AND C. KITTEL, *University of California, Berkeley.*—The line width observed in electronic spin resonance in alkali metals[1] is attributed to the diffusion of conduction electrons. A conduction electron in the skin depth will see an rf field which is amplitude and frequency modulated, giving rise to a line width. This width is "motionally narrowed" because of the high frequency of electron-phonon collisions. The relative width $\Delta\omega/\omega$ is proportional to the square of the conductivity mean free path A. For alkali metal samples of dimensions greater than the skin depth, $\Delta\omega/\omega\approx10^{-1}$ to 10^{-2}. If the thickness t of the sample is less than the skin depth δ, there is additional narrowing by a factor $\alpha(t/\delta)^2$. Although electron-electron collisions do not contribute to the conductivity, they play a role in determining the width. We must therefore replace A^2 by $A\Lambda'$, where $(\Lambda')^{-1}=\Lambda^{-1}+\Lambda_e^{-1}$, and Λ_e is the electron-electron collision mean free path. The affect of such collisions should be observable in the variation of width with temperature at temperatures low enough that $\Lambda_e<\Lambda$. Calculations of Λ_e will be presented.

[1] Griswold, Kip, and Kittel, Phys. Rev. (to be published).

N7. Measurement of the Transport Mean Free Path of Thermal Neutrons in Heavy Water. S. W. KASH AND D. C. WOODS, *Atomic Energy Research Department, North American Aviation, Inc.**—The transport mean free path of thermal neutrons in heavy water has been experimentally determined by a boron poisoning technique. The method involved measuring the relaxation length of thermal neutrons in a cylindrical tank containing a mixture of heavy water and boron. From the variation of the relaxation length with boron concentration, the effective value of the transport mean free path and the hydrogen impurity content were determined for the heavy water used. Correcting for the hydrogen impurity yielded a value of 2.53 ± 0.03 cm for the transport mean free path of 100 percent pure D_2O.

* Work supported by the AEC.

N8. Pulse-Height Measurements of Recoils from $B^{10}(n,\alpha)Li^7$ in Argon-CO_2 Mixtures. J. DE JUREN AND H. ROSENWASSER, *National Bureau of Standards.*—Thin films of boron deposited over a small area by vacuum evaporation have been exposed to a slow neutron flux in an ionization chamber connected to a linear amplifier. The resulting pulse-height distributions have been analyzed for a variety of pressures, field strengths, and amplifier time constants. A considerable variation in the ratio of the He^4 and Li^{7*} pulses was observed. Other authors[1,2,3] have obtained ratios from 1.84 to 1.89, whereas from conservation of momentum 1.753 is expected. These values have been cited as evidence for an increase in the average energy loss per ion pair created in argon as particle velocity is reduced. Our measurements agree with the above ratios for certain conditions but decrease to a value approaching 1.75 as pressure is reduced and field strength is increased, indicating that electron capture at the end of the Bragg curve is responsible for most of the variation.

[1] Stebler, Huber, and Bichsel, Helv. Phys. Acta **22**, 362 (1949).
[2] G. C. Hanna, Phys. Rev. **80**, 530 (1950).
[3] Rhodes, Franzen, and Stephens, Phys. Rev. **87**, 141 (1952).

N9. A Trochoidal Analyzer for Charged Particles. BERND CRASEMANN, *University of California, Berkeley.*—A magnetic analyzer has been built which makes use of the trochoidal

orbit of charged particles in a fringing magnetic field.[1] The source is placed in a vacuum chamber at the edge of a 2-cm gap between cylindrical pole pieces of 10-cm diameter. At this radius, the field, which reaches 9000 gauss at the center of the gap, has a linear gradient of 3000 gauss/cm. The particles describe approximately circular orbits that precess at right angles to the field gradient. The detector is a scintillation counter. Background is practically eliminated by dividing the light pulses from an anthracene crystal through a split Lucite light pipe and counting them with two cooled 1P21 photomultipliers in coincidence. Rough energy resolution is provided by varying the amplifier bias. Positrons and electrons can be counted with good efficiency. The apparatus has been used to study a 4-min positron activity obtained in cyclotron bombardments of Co, Ni^{60}, and Ni^{61} with alpha-particles, Ni^{61} and Ni^{62} with deuterons, Ni^{62} with protons, and Cu with neutrons.

[1] J. Thibaud, Compt. rend. **197**, 447 (1933).

SUPPLEMENTARY PROGRAMME

SP1. Characteristics of Certain Photographic Plates in the Vacuum Ultraviolet. Po Lee and G. L. Weissler,* *University of Southern California.*—The D *vs* log$t$ curves of Eastman 103a–0 ultraviolet-sensitized plates have been studied in the near and the vacuum ultraviolet, respectively, together with the absorption and fluorescence spectrum of the sensitization lacquer. It was found that the ultraviolet-sensitization effect of the plate began at about 3000A, where the threshold absorption spectrum of the lacquer occurred. The absorption in the near ultraviolet did not reach total extinction for a lacquer thickness comparable to that on the commercially sensitized plates. The contrasts γ, obtained from the slopes of the D *vs* log$t$ curves calibrated in the vacuum spectrograph, were constant within an experimental deviation of 4 percent throughout all observed wavelengths from 1320A to 360A and were equal to the contrast of the emulsion at the wavelength of maximum intensity of fluorescence of this lacquer, 3150A. A number of methods for the calibration of plates in air has been suggested and one of them was tested in detail. The reciprocity law and sensitivity of these ultraviolet-sensitized plates were also studied and are discussed.

* The aid of ONR and the Cambridge Air Force Research Center is gratefully acknowledged.

SP2. The Absorption Coefficients of NO and NH_3 in the Vacuum Ultraviolet. H. Sun and G. L. Weissler,* *University of Southern California.*—The NO absorption between 1300A and 370A is composed of one or more continuous regions superposed by bands. A plot of the coefficients k_ν *versus* wavelength exhibits at least two maxima, one at 920A with $k_\nu = 850$ cm^{-1} and another at 620A with $k_\nu = 920$ cm^{-1}. There are also indications of small peaks at 1300A with $k_\nu = 180$ cm^{-1} and at 760A with $k_\nu = 660$ cm^{-1}. An absorption minimum occurs near 1200A with $k_\nu \leq 50$ cm^{-1}. It has not been possible as yet to separate band absorption from continuous absorption. For this reason, the ionization continua associated with the various ionization limits of Tanaka[1] have not been correlated with these measurements. (NH_3 shows in the same region a nearly continuous absorption with a broad maximum of about $k_\nu = 1000$ cm^{-1} at 770A.) Experimental details and k_ν values for 80 wavelengths will be presented for both gases.

* The aid of ONR is gratefully acknowledged.

[1] Y. Tanaka, Sci. Pap. Inst. Phys. Chem. Res., Tokyo **39**, 456 (1942).

Author Index to Papers Presented at the Inyokern-Pasadena Meeting

Abrahams, Elihu and C. Kittel—N6
Amin, M. R.—I10
Anderson, A. B. C.—M10
Antonoff, George—M3
Ashburn, E. V.—H13
Ball, W. P., Burton J. Moyer, and Robert E. Richardson—K14
Benedict, W. S., Norman Gailar, and Earle K. Plyler—H7
Bennett, Arthur L.—M12
Bowen, D. B. and G. W. Rodeback—G6
Bradley, Richard C.—I7
Bratenahl, A. and B. J. Moyer—K9
Brinkman, J.—G3
Brown, Karl L. and Richard Wilson—L4
Brown, S. Leroy and John M. Norwood—I1
Carothers, James Edward—K10
Chiang, S. F. and S. A. Schaaf—I3
Christy, R. F.—F10
Conger, Robert L.—M13
Cooper, E. P.—C1
Crasemann, Bernd—N9
De Juren, J. and H. Rosenwasser—N8
Denney, J. M.—G7
Deutsch, R. W. and W. H. Barkas—K15
Dixon, C. E. and C. J. Meechan—G2
Dunbar, D. N. F., H. K. Reynolds, W. A. Wenzel, and W. Whaling—F4
Dyke, W. P. and J. K. Trolan—L12
Easterday, Harry T.—K5
Eggleston, R. R.—G5
Eggen, D. T. and H. Kenworthy—G8
Eisberg, Robert M. and George J. Igo—K1
El-Sum, Hussein M. A. and Paul Kirkpatrick—L11
Feynmann, Richard C.—J4
Ford, Franklin C. and Wilson M. Powell—K3
Fowler, C. A., Jr., and E. M. Fryer—G10
Frank, Wilson J., Kenneth C. Bandtel, Richard Madey, and Burton J. Moyer—K6
Gaydon, A. G.—A6
Goldman, J. E.—E2
Good, Myron L.—K11
Guinier, Andre—E3
Hendrick, R. W., Jr.—L9
Hofstadter, Robert and Asher Kantz—J5
Horton, C. W.—C3
Howe, H. A. and K. R. MacKenzie—F14
Hoyle, Fred—IA1
Huber, Elsa—I8
Hunt, M. H., C. A. Heller, and A. S. Gordon—M5
Jankus, V. Z.—L6
Kash, S. W. and D. C. Woods—N7
Keywell, Frank—I4
Kip, A. F., T. W. Griswold, and A. M. Portis—N5
Kittel, C.—E1
Knight, W. D.—L1
Koehler, W. F.—M1
Kraus, Alfred A., Jr., A. P. French, William A. Fowler, and C. C. Lauritsen—F6
Kretschmar, George G.—M8
Krzywoblocki, M. Z.—C5
Kunkel, W. B.—H11
Kyhl, R. L.—J1
Langmuir, R. V.—J2
Lawson, R. D. and S. D. Drell—L2
Lee, Po and G. L. Weissler—H5
Lee, Po and G. L. Weissler—SP1
Leighton, R. B. and W. L. Alford—L7
Leighton, Robert B.—J3
Leonard, Stanley L.—K13
Liepmann, H. W.—C4
Lomont, J.—G9
Mackin, R. J., Jr.—F8
Madey, Richard, Kenneth C. Bandtel, and Wilson J. Frank—K4
Meyerhof, W. E., L. G. Mann, and H. I. West, Jr.—L5
Mileikowsky, Curt and Ward Whaling—F5
Milne, Edmund A.—F2
Motz, H. and L. I. Schiff—L8
Neal, R. B.—L13
Norrish, R. G. W.—A5
Oliver, Albert J.—K12
Overhauser, Albert W.—G1
Papas, Charles H.—M2
Parker, James H.—I9
Parker, Lee W. and John R. Holmes—H1
Pattee, Howard H., Jr.—L10
Peterson, John W.—I6
Pitkanen, Paul H.—F13
Plain, G. J., H. L. Morrison, P. H. Pitkanen, and F. T. Rogers, Jr.—F11
Plesset, M. S.—C2
Porter, G.—A4
Price, E. W.—M7
Rekers, R. G. and D. S. Villars—H8
Remley, M. E. and D. C. Woods—N4
Reynolds, H. K., D. N. F. Dunbar, W. A. Wenzel, and W. Whaling—F3
Roach, F. E., Helen B. Pettit, D. R. Williams, and P. St. Amand—H10
Rogers, F. T., Jr.—I2
Rogers, Marguerite, F. K. Odencrantz, and G. J. Plain—F12
Sagane, Ryokichi—K16
St. Amand, Pierre and D. R. Williams—H9
Schilberg, Lloyd E. and A. B. C. Anderson—M9
Shook, G. B.—M4
Silverman, S.—A1
Stapp, H. P.—L3
Stork, D.—K8
Stuart, Alexander Verrijn and G. B. B. M. Sutherland—H12
Sun, H. and G. L. Weissler—SP2
Swings, P.—A3
Tannenwald, L. M.—M6
Theobald, J. K.—I5
Tracy, J. F.—K2
Truby, Frank K.—N2
Wainfan, N. and W. C. Walker—H2
Walker, W. C. and N. Wainfan—H3
Wallin, W.—M11
Warters, William D.—F1
Weissler, G. L. and H. Sun—H4
Westervelt, Donald R.—G4
Williams, D. R. and Pierre St. Amand—H6
Wilson, H. W. and Walter H. Barkas—K7
Wise, Henry—G12
Wolfhard, H. G.—A2
Wong, Calvin—F9
Woodbury, H. Hugh—F7
Workman, E. J.—N3
Yadoff, Oleg—N1
Zernow, Louis—G11

316TH MEETING

of the

AMERICAN PHYSICAL SOCIETY

December 26 and 27, 1952

U. S. NAVAL ORDNANCE TEST STATION

Inyokern, China Lake, California

Name ..... (please print)

Residence ..... Street City State

Organization .....

Address ..... Street City State

Arrival ..... Date and Hour Departure ..... Date and Hour

☐ I wish to stay at BOQ. NOTE: BOQ space is limited to 175 persons, and will be allotted in the order of receipt of this form. The Station will attempt to locate additional personnel in off-Station housing.

☐ I have made other housing arrangements.

I will travel by:

☐ California Central Airlines

- ☐ I will require transportation from the Hotel Constance, Pasadena, to the Burbank Airport, Friday, December 26.
- ☐ I will require transportation from the Burbank Airport to the Hotel Constance, Pasadena, Saturday, December 27.

NOTE: Round trip plane fare to NOTS will be $16.00 plus $2.40 tax. Travel requisitions, checks, or money orders should be made payable to California Central Airlines and should be returned with this form. Reservations will not be made without payment in advance, and tickets are not refundable on chartered flights.

☐ Greyhound Bus

☐ Private Car

☐ Other Means (Please specify) .....

I plan to eat the following meals at the Commissioned Officers Club:

☐ Lunch, December 26
☐ Dinner, December 26
☐ Breakfast, December 27
☐ Lunch, December 27

Mail to:

Dr. William B. Plum
Room 20103, Michelson Laboratory
U. S. Naval Ordnance Test Station
China Lake, California

PLEASE RETURN THIS FORM NO LATER THAN DECEMBER 15